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# ARTILLERY SAFETY AND ARMING DEVICE

Breed Corporation

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Harry Diamond Laboratories

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ARTILLERY SAFETY AND ARMING DEVICE

FINAL REPORT

By

BREED CORPORATION

Fairfield, New Jersey

February, 1972



For

HARRY DIAMOND LABORATORIES

Washington, D. C.

CONTRACT NO. DAAG-39-71-C-0002

The findings in this report are not to be construed as an official Department of the Army position unless so designated.

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# ARTILLERY SAFETY AND ARMING DEVICE

## 1. Background, Statement of the Problem

The objective of the program was to design and develop a safety and arming device for general artillery use incorporating dashpot functions to delay arming and self-destruction. The concept involved the replacement of the gear driven runaway escapement of the current M125A1 booster (Ordnance Partn No. 8595541) with a simpler mechanism utilizing a Sharp Edge Orifice Dashpot (SEOD) for arming delay and a Liquid Annular Orifice Dashpot (LAOD) for self-destruct to "clean up" dud rounds.

The work was to be based upon Breed Corporation's unsolicited proposal dated May 23, 1969, "Artillery Booster Assembly" and AMXDO-DAS, Branch 420, of Harry Diamond Laboratories' Technical Evaluation of Breed's proposal dated June 27, 1969, as incorporated into the Statement of Work DAAG-39-70-R-3047 of January 19, 1972.

In addition, the program sought a solution for QMRI Problem No. 72, "High Performance Artillery and Mortar Point Detonating Fuzes" which requires a substantial reduction of overall duds without affecting safety levels, increased manufacturability to eliminate human error, and, if possible, also reduce costs.

## 2. Description of Operation

The artillery safety and arming device (Breed Drawing No. 508970) when attached to a fuze and fired from an artillery gun or howitzer remains out-of-line for at least 70 meters after leaving the barrel of the gun.

The setback is recorded on a SHEARFLOD and upon experiencing a proper setback acceleration, the SHEARFLOD piston begins moving downward in its cylinder with its motion being opposed by a bias force from the SHEARFLOD spring and a viscous shearing force resulting from the relative motion of the SHEARFLOD pin and its cylinder. Once the spinning projectile exits from the muzzle, the two slider detent pins begin moving outward against their respective slider detent springs due to centrifugal acceleration. Thus, under a proper firing environment, the three detents are removed from locking the slider weight assembly which is now free to move radially outward also due to centrifugal acceleration. After a short motion, the slider weight assembly impacts on the timing pin which punctures a foil seal in the SEOD assembly and bears on the SEOD piston. This creates a pressure in the five centistoke silicone fluid which prevents further motion of the SEOD piston assembly except at the rate determined by the flow of the fluid through the sharp edge orifice in the SEOD piston. The flow rate of the fluid through the hole thus determines the time it takes for the slider weight assembly to move to its outermost radial position.

When the slider weight assembly reaches its outermost radial position, three detonators become aligned with three lead cup assemblies. The fuze is now armed and can be initiated in one of two modes. Any standard artillery fuze placed above the artillery S & A booster assembly which can currently be used with the standard M125 can be used with this S & A. The explosive output of such fuzes is sufficient to ignite the M55 detonator. This detonator in turn will ignite both modified XM-76-E3, 50 millisecond delay detonators and in turn ignite all three lead cup assemblies which carry the explosion to the main explosive charge. In addition, any new fuze having nothing more than a firing pin positioned above the aligned M55 detonator can be used to initiate the round. If the primary fuze fails or if in the second example the firing pin is removed or locked out, impact of the projectile with a target causes both modified XM-76-E3, 50 millisecond delay detonators to move forward against firing pins in the cover resulting in initiation of the main charge redundantly in the delay mode.

The SHEARFLOS setback pin differs from conventional spring mass setback pins in that it requires an acceleration of above a minimum magnitude and also lasting for a significant duration. Thus, the setback pin will accurately differentiate between 20 foot drop and a minimum g mortar firing, for example, significantly increasing the drop safety of the round.

The design in addition contains three redundant explosive trains which greatly increase the reliability of the projectile exploding in the superquick and delay modes and significantly reduces the incidence of duds.

Every part in the S & A has been designed for production on high volume mass production machines. Most parts are stamped, drawn or extruded with a minimum of parts requiring metal cutting. In addition, all of the non-explosive parts are made from aluminum or steel, thus eliminating the need for critical materials such as copper and brass.

## 3. Theory

### 3.1 General SEOD

The timer or integrator used in this artillery S & A is based on the SEOD, or Sharp Edge Orifice Dashpot, technology. The simplest embodiment of the SEOD consists of a piston having a sharp edge orifice traveling in a cylinder in such a manner that the predominant fluid flow occurs through the sharp edge orifice with the flow in a clearance between the piston and cylinder being negligible. In addition, flow in the orifice must be at sufficiently large Reynolds numbers so that viscous effects in the orifice can be neglected. In all cases the resistance to the motion of the piston arises from the inertial flow of the fluid through the orifice and the dynamics of the piston can be neglected.

Bernoulli's equation for this case becomes simply:

$$\frac{P}{\rho} = \frac{V^2}{2} \tag{3.1.1}$$

Therefore,

$$V = \sqrt{\frac{2P}{\rho}}$$

and,

$$Q = KBV = KB\sqrt{\frac{2P}{\rho}} \tag{3.1.2}$$

Also,

$$\dot{X} = \frac{Q}{A} = \frac{KB}{A}\sqrt{\frac{2P}{\rho}}$$

giving

$$t = \frac{LA}{KB}\sqrt{\frac{\rho A}{2F}} \tag{3.1.3}$$

Where:

$t$ = time delay (sec.)

$L$ = length of piston travel (in.)

$A$ = area of piston cross section ($in^2$)

$B$ = area of orifice ($in^2$)

$\rho$ = density $\frac{lbs.\ sec^2}{in^4}$

$K$ = experimental orifice constant (approximately .7)

$F$ = force (lbs.)

$V$ = velocity of fluid in orifice ($\frac{in}{sec}$)

$\dot{X}$ = velocity of piston ($\frac{in}{sec}$)

$Q$ = volume flow rate ($in^3$/sec)

$P$ = pressure drop across orifice

The time delay as expressed by equation (3.1.3) is not dependent on the viscosity of the fluid and thus accuracy should be relatively independent of temperature. However, for equation (3.1.3) to be accurate, the flow through the clearance must be negligible over the entire temperature range of operation. In addition, viscous effects in the orifice must be negligible which implies that the Reynolds number must be significantly greater than 1 and that the ratio of the length to diameter of the orifice should be small.

The flow through the clearance between the piston and cylinder can be approximated by a flow through a rectangular slit since $h<<R$. For a liquid under the conditions here the flow can be considered steady state and incompressible. For the case where the piston and cylinder axes are parallel, as will be assumed here, the flow is one dimentional. For these assumptions the equations of motion reduce to:

$$\frac{dP}{dX} = \mu \frac{d^2V_x}{dY^2} \qquad (3.1.4)$$

Integrating equation (3.1.4) twice yields:

$$\mu V_x = \frac{dP}{dX}\frac{Y^2}{2} + C_1 Y + C_2 \qquad (3.1.4)$$

Assuming no slip at the walls and that the velocity of the piston can be neglected with respect to mid-stream fluid velocity

$$V_x = 0 \text{ at } Y = 0, h$$

which yields:

$$C_2 = 0$$

$$C_1 = -\frac{dP}{dX}\ \frac{h}{2}$$

Thus,

$$V_x = \frac{1}{2\mu}\ \frac{dP}{dX}\,(Y^2 - hY) \qquad (3.1.6)$$

which is the familiar parabolic velocity profile.

The total flow of fluid can now easily be found by integrating:

$$Q = \int_0^h 2\pi R V_x dY = \frac{\pi R}{\mu}\frac{dP}{dX} \int_0^h (Y^2 - hY)dY$$

Thus,

$$Q = \frac{\pi R h^3}{6\mu}\ \frac{dP}{dX} \qquad (3.1.7)$$

and since the pressure gradient is constant providing the piston and cylinder axes are parallel and the clearance is constant, equation (3.1.7) becomes:

$$Q = \frac{\pi R h^3 (P_2 - P_1)}{6\mu L} \qquad (3.1.8)$$

The pressure drop can be related to the force applied to the piston,

$$F = (P_2 - P_1)\pi R^2$$

Also, assuming negligible piston acceleration, the velocity of the piston can be related to the volume flow rate,

$$Q = \frac{\pi R^2 L}{t}$$

Substituting these equations into 3.1.8 and rearranging, yields

$$t = \frac{6\pi\mu R^3 LL'}{h^3 F} \qquad (3.1.9)$$

When the piston is resting against the side of the cylinder the local clearance can be related to the mean radial clearance by the relation

$$h = H(1-\cos\theta)$$

where second order terms have been neglected.

Substituting this into (3.1.9) and integrating from $\theta = 0$ to $2\pi$ yields

$$t = \frac{6\pi\mu R^3 LL'}{2.5H^3 F} \qquad (3.1.10)$$

Where:

$\mu$ = viscosity

$R$ = piston radius

$L$ = length of piston travel

$L'$ = length of piston

$h$ = clearance

$F$ = force applied to piston

$\theta$ = angular coordinate around piston

$Q$ = flow rate through clearance

$V_x$ = fluid velocity in X direction

$X$ = coordinate axis parallel to direction of motion

$Y$ = coordinate axis perpendicular to piston and cylinder walls

$P_2$ = pressure inside cylinder

$P_1$ = atmosphere pressure

$H$ = mean radial clearance

For the flow in the clearance to be negligible, therefore, the ratio of the time delay due to flow through the clearance to the time delay for flow through the orifice must be large. Therefore, dividing equation (3.1.10) by equation (3.1.3) yields:

$$\frac{t_c}{t_o} = \frac{K'\mu L'B}{H^3\sqrt{\rho F}}$$

Where:

$$K' = \frac{6K\sqrt{2}}{2.5\sqrt{\pi}} = 1.34$$

$t_c$ = time for travel if all fluid traveled through the clearance (sec.)

$t_o$ = time for travel if all fluid traveled through the orifice (sec.)

$\mu$ = viscosity (lb.sec/in$^2$)

$L'$ = length of piston (in.)

$\rho$ = density $\left(\frac{\text{lb.sec}^2}{\text{in}^4}\right)$

$B$ = area of orifice (in$^2$)

$F$ = applied force (lbs)

The second condition that viscous effects should be negligible for the flow through the orifice, requires that the Reynolds number should be much greater than one. Thus;

$$R_e = \frac{Vd}{\nu} >> 1$$

Where:

$V$ = fluid velocity (in/sec)

$\nu$ = kinematic viscosity ($in^2$/sec)

$d$ = diameter or orifice

The fluid velocity can be evaluated from the flow (Q) through the orifice for steady state flow:

$$V = \frac{Q}{B} = \frac{4Q}{\pi d^2}$$

and

$$\dot{Q} = \frac{R^2 L \pi}{t_c}$$

Therefore;

$$R_e = \frac{4R^2 L}{t_o d \nu} \qquad (3.1.11)$$

These equations have been programmed in a slightly different form to permit a numerical integration of the weight travel since the force on the piston varies as the weight moves to a larger distance from the spin axis. Some representative results are shown in Tables 3.1 to 3.6.

Column 1 in the tables represents the angular velocity of the projectile. Column 2 is the time required for the weight to travel from a radius of .075 inch to .325 inch. This is calculated by numerically integrating the piston velocity over time where the piston velocity is the sum of the velocity due to flow through the clearance and the flow through the hole. Column 3 is the leak ratio which is the ratio of the total flow through the clearance to the total flow through the orifice. Column 4 is the Reynolds number calculated according to equation (3.1.11) with the travel due to the flow through the orifice substituted for L.

The results in Tables 3.1 through 3.6 show the spin rate, time, leak ratio, Reynolds number and turns to arm for fluids of 1 centistoke, 5 centistoke, and 50 centistoke viscosity. For Each viscosity runs are made at 165°F and at -65°F. Looking at Table 3.1 and 3.2 for the 1 cs oil, the turns to arm ratio stays remarkably constant at -65°, however, varies considerably at 165°F. For 5 centistoke fluid, however, the variation is much less not only as a function of spin but also as a function of temperature. Similarly with 50 centistoke fluid, good results are also obtained except for the fact that at -65° the Reynolds number gets quite low which casts doubt on the assumption of inertial flow through the orifice. Since little accuracy is gained by going from 5 to 50 centistoke fluid, 5 centistoke fluid was chosen for this application.

TABLE 3.1

ARTILLERY SPOD PROGRAM - 11/26/70
REVISED - 12/14/71

FLUID IS 1 CENTISTOKE SILICONE
FLUID VISCOSITY = .2 CENTIPOISE
TEMPERATURE = 165 DEG.F
DENSITY OF FLUID = .77[illegible]1 GMS/CU.CM
MEAN RADIAL CLEARANCE = 1.25000E-04 INCHES
ORIFICE DIAMETER = 5.00000E-03 INCHES

| SPIN (RPM) | TIME | LEAK RATIO | REYNOLDS NO. | TURNS TO ARM |
|---|---|---|---|---|
| 2000 | 1.25 | 6.07918E-02 | 5528.94 | 42 |
| 3000 | .8125 | 9.14302E-02 | 8314.31 | 41 |
| 4000 | .59375 | .12137 | 11035.7 | 40 |
| 5000 | .460937 | .152037 | 13826.9 | 39 |
| 6000 | .375 | .181994 | 16549.3 | 38 |
| 7000 | .3125 | .211356 | 19222.6 | 36 |
| 8000 | .273437 | .243267 | 22093.5 | 36 |
| 9000 | .230469 | .271769 | 24723.2 | 35 |
| 10000 | .203125 | .30159 | 27432.4 | 34 |
| 11000 | .183594 | .333414 | 30296.9 | 34 |
| 12000 | .164062 | .362391 | 32936.8 | 33 |
| 13000 | .148437 | .391974 | 35622.5 | 32 |
| 14000 | .136719 | .423554 | 38453.2 | 32 |
| 15000 | .125 | .45279 | 41118. | 31 |
| 16000 | .113281 | .483679 | 43947. | 30 |
| 17000 | .103516 | .510896 | 46454. | 29 |
| 18000 | 9.76562E-02 | .544461 | 49458.6 | 29 |
| 19000 | 8.98437E-02 | .57124 | 51516.9 | 28 |
| 20000 | 8.39844E-02 | .601043 | 54617.7 | 28 |
| 21000 | 7.81250E-02 | .628674 | 57148.5 | 27 |
| 22000 | 7.42187E-02 | .661433 | 60077.1 | 27 |
| 23000 | 7.03125E-02 | .6929 | 62903.9 | 27 |
| 24000 | 6.64062E-02 | .722779 | 65605.1 | 27 |
| 25000 | 6.25000E-02 | .750764 | 68160.9 | 26 |

MAXIMUM HOLE LENGTH = .298563 IN.

TABLE 3.2

ARTILLERY SEOD PROGRAM - 11/26/70
REVISED - 10/14/71

FLUID IS 1 CENTISTOKE SILICONE
FLUID VISCOSITY = 10 CENTIPOISE
TEMPERATURE = -65 DEG.F
DENSITY OF FLUID = .88344 GMS/CU.CM
MEAN RADIAL CLEARANCE = 1.25000E-04 INCHES
ORIFICE DIAMETER = 5.40000E-03 INCHES

| SPIN (RPM) | TIME | LEAK RATIO | REYNOLDS NO. | TURNS TO ARM |
|---|---|---|---|---|
| 2000 | 1.40625 | 1.29996E-03 | 118.261 | 47 |
| 3000 | .9375 | 1.95571E-03 | 177.919 | 47 |
| 4000 | .703125 | 2.60188E-03 | 236.611 | 47 |
| 5000 | .5625 | 3.24319E-03 | 294.997 | 47 |
| 6000 | .46875 | 3.91407E-03 | 356.042 | 47 |
| 7000 | .398437 | 4.54563E-03 | 413.648 | 46 |
| 8000 | .351562 | 5.20681E-03 | 473.579 | 47 |
| 9000 | .3125 | 5.85094E-03 | 532.134 | 47 |
| 10000 | .28125 | 6.49356E-03 | 590.546 | 47 |
| 11000 | .253906 | 7.16037E-03 | 652.202 | 47 |
| 12000 | .234375 | 7.83875E-03 | 712.901 | 47 |
| 13000 | .214844 | 8.46384E-03 | 769.997 | 47 |
| 14000 | .199219 | 9.12545E-03 | 828.389 | 46 |
| 15000 | .1875 | 9.78400E-03 | 889.762 | 47 |
| 16000 | .175781 | 1.04323E-02 | 948.593 | 47 |
| 17000 | .164062 | 1.10411E-02 | 1004.35 | 46 |
| 18000 | .15625 | 1.17253E-02 | 1066.07 | 47 |
| 19000 | .148437 | 1.23852E-02 | 1125.84 | 47 |
| 20000 | .140625 | 1.30160E-02 | 1183.31 | 47 |
| 21000 | .132812 | 1.36133E-02 | 1239.1 | 46 |
| 22000 | .125 | 1.42815E-02 | 1299.95 | 46 |
| 23000 | .121094 | 1.50055E-02 | 1364.96 | 46 |
| 24000 | .115234 | 1.56119E-02 | 1420.51 | 46 |
| 25000 | .111328 | 1.63026E-02 | 1482.9 | 45 |

MAXIMUM HOLE LENGTH = 6.38607E-03 IN.

TABLE 3.3

ARTILLERY SEOD PROGRAM - 11/26/70
REVISED - 10/14/71

FLUID IS 5 CENTISTOKE SILICONE
FLUID VISCOSITY = 2 CENTIPOISE
TEMPERATURE = 165 DEG.F
DENSITY OF FLUID = .9405 GMS/CU.CM
MEAN RADIAL CLEARANCE = 1.25000E-04 INCHES
ORIFICE DIAMETER = 5.40000E-03 INCHES

| SPIN (RPM) | TIME | LEAK RATIO | REYNOLDS NO. | TURNS TO ARM |
|---|---|---|---|---|
| 2000 | 1.4375 | 6.69561E-03 | 609.244 | 48 |
| 3000 | .953125 | 1.00595E-02 | 915.472 | 48 |
| 4000 | .71875 | 1.34219E-02 | 1220.65 | 48 |
| 5000 | .578125 | 1.67889E-02 | 1526.33 | 48 |
| 6000 | .476562 | 2.01886E-02 | 1836.3 | 48 |
| 7000 | .40625 | 2.34954E-02 | 2137.28 | 47 |
| 8000 | .351562 | 2.67244E-02 | 2431.96 | 47 |
| 9000 | .3125 | 3.00574E-02 | 2734.74 | 47 |
| 10000 | .28125 | 3.33884E-02 | 3037.22 | 47 |
| 11000 | .257812 | 3.66436E-02 | 3349.39 | 47 |
| 12000 | .234375 | 4.03797E-02 | 3672.19 | 47 |
| 13000 | .214844 | 4.36381E-02 | 3969.26 | 47 |
| 14000 | .199219 | 4.69877E-02 | 4273.47 | 46 |
| 15000 | .183594 | 5.01024E-02 | 4559.02 | 46 |
| 16000 | .171875 | 5.34327E-02 | 4861.55 | 46 |
| 17000 | .164062 | 5.71275E-02 | 5192.82 | 46 |
| 18000 | .152344 | 6.00881E-02 | 5465.97 | 46 |
| 19000 | .144531 | 6.34079E-02 | 5773.76 | 46 |
| 20000 | .136719 | 6.67360E-02 | 5069.48 | 46 |
| 21000 | .132812 | 7.06810E-02 | 6420.21 | 46 |
| 22000 | .123047 | 7.37439E-02 | 6700.64 | 45 |
| 23000 | .117187 | 7.70147E-02 | 7006.62 | 45 |
| 24000 | .111328 | 8.01327E-02 | 7292.47 | 45 |
| 25000 | .107422 | 8.37080E-02 | 7614.43 | 45 |

MAXIMUM HOLE LENGTH = 3.28992E-02 IN.

TABLE 3.4

ARTILLERY SEOD PROGRAM - 11/26/70
REVISED - 10/14/71

FLUID IS 5 CENTISTOKE SILICONE
FLUID VISCOSITY = 100 CENTIPOISE
TEMPERATURE = -65 DEG.F
DENSITY OF FLU.D = 1.0692 GMS/CU.CM
MEAN RADIAL CLEARANCE = 1.25000E-04 INCHES
ORIFICE DIAMETER = 5.40000E-03 INCHES

| SPIN (RPM) | TIME | LEAK RATIO | REYNOLDS NO. | TURNS TO ARM |
|---|---|---|---|---|
| 2000 | 1.5625 | 1.43600E-04 | 13.0652 | 52 |
| 3000 | 1.03125 | 2.13579E-04 | 19.4297 | 52 |
| 4000 | .78125 | 2.87374E-04 | 25.1314 | 52 |
| 5000 | .625 | 3.50339E-04 | 32.5827 | 52 |
| 6000 | .515625 | 4.27189E-04 | 38.8619 | 52 |
| 7000 | .445312 | 5.03049E-04 | 45.7496 | 52 |
| 8000 | .390625 | 5.74806E-04 | 52.2672 | 52 |
| 9000 | .34375 | 6.43218E-04 | 58.5173 | 52 |
| 10000 | .3125 | 7.16766E-04 | 65.1723 | 52 |
| 11000 | .28125 | 7.84246E-04 | 71.3439 | 52 |
| 12000 | .257812 | 8.54581E-04 | 77.7333 | 52 |
| 13000 | .238281 | 9.32552E-04 | 84.8375 | 52 |
| 14000 | .222656 | 1.00627E-03 | 91.5127 | 52 |
| 15000 | .207031 | 1.07585E-03 | 97.8578 | 52 |
| 16000 | .195312 | 1.14984E-03 | 104.552 | 52 |
| 17000 | .183594 | 1.22035E-03 | 110.969 | 52 |
| 18000 | .171875 | 1.28672E-03 | 117.857 | 52 |
| 19000 | .164062 | 1.36168E-03 | 123.918 | 52 |
| 20000 | .15625 | 1.43389E-03 | 130.372 | 52 |
| 21000 | .148437 | 1.50314E-03 | 136.684 | 52 |
| 22000 | .140625 | 1.56891E-03 | 142.72 | 52 |
| 23000 | .136719 | 1.65027E-03 | 149.99 | 52 |
| 24000 | .128906 | 1.72950E-03 | 155.505 | 52 |
| 25000 | .123047 | 1.78937E-03 | 162.839 | 51 |

MAXIMUM HOLE LENGTH = 7.05519E-04 IN.

TABLE 3.5

ARTILLERY SEOD PROGRAM - 11/26/70
REVISED - 10/14/71

FLUID IS 50 CENTISTOKE SILICONE
FLUID VISCOSITY = 20 CENTIPOISE
TEMPERATURE = 165 DEG.F
DENSITY OF FLUID = .9405 GMS/CU.CM
MEAN RADIAL CLEARANCE = 1.25000E-04 INCHES
ORIFICE DIAMETER = 5.40000E-03 INCHES

| SPIN (RPM) | TIME | LEAK RATIO | REYNOLDS NO. | TURNS TO ARM |
|---|---|---|---|---|
| 2000 | 1.46875 | 6.74053E-04 | 61.2862 | 49 |
| 3000 | .96875 | 1.00948E-03 | 91.8344 | 48 |
| 4000 | .734375 | 1.34640E-03 | 122.597 | 49 |
| 5000 | .578125 | 1.67029E-03 | 151.973 | 48 |
| 6000 | .484375 | 2.01967E-03 | 183.723 | 48 |
| 7000 | .414062 | 2.35869E-03 | 213.871 | 48 |
| 8000 | .359375 | 2.67457E-03 | 243.415 | 48 |
| 9000 | .320312 | 3.02856E-03 | 273.762 | 48 |
| 10000 | .289062 | 3.34248E-03 | 304.092 | 48 |
| 11000 | .265625 | 3.68852E-03 | 335.369 | 49 |
| 12000 | .242187 | 4.04217E-03 | 367.664 | 48 |
| 13000 | .222656 | 4.35939E-03 | 397.5 | 48 |
| 14000 | .207031 | 4.70551E-03 | 428.035 | 48 |
| 15000 | .191406 | 5.01939E-03 | 456.801 | 48 |
| 16000 | .175627 | 5.35403E-03 | 487.206 | 48 |
| 17000 | .171875 | 5.72333E-03 | 520.354 | 49 |
| 18000 | .160156 | 6.0233.E-03 | 548. | 48 |
| 19000 | .152344 | 6.36499E-03 | 578.946 | 48 |
| 20000 | .144531 | 6.69259E-03 | 605.769 | 49 |
| 21000 | .136719 | 7.00399E-03 | 637.294 | 48 |
| 22000 | .132812 | 7.38635E-03 | 671.453 | 49 |
| 23000 | .125 | 7.72577E-03 | 702.98 | 49 |
| 24000 | .119141 | 8.04205E-03 | 731.95 | 48 |
| 25000 | .115234 | 8.40069E-03 | 764.293 | 49 |

MAXIMUM HOLE LENGTH = 3.30945E-03 IN.

TABLE 3.6

ARTILLERY SEOD PROGRAM - 11/26/70
REVISED - 12/14/71

FLUID IS 50 CENTISTOKE SILICONE
FLUID VISCOSITY = 1200 CENTIPOISE
TEMPERATURE = -55 DEG.F
DENSITY OF FLUID = 1.0592 GMS/CU.CM
MEAN RADIAL CLEARANCE = 1.25000E-04 INCHES
ORIFICE DIAMETER = 5.40000E-03 INCHES

| SPIN (RPM) | TIME | LEAK RATIO | REYNOLDS NO. | TURNS TO ARM |
|---|---|---|---|---|
| 2000 | 1.5625 | 1.43674E-05 | 1.30547 | 52 |
| 3000 | 1.03125 | 2.13565E-05 | 1.94287 | 52 |
| 4000 | .78125 | 2.87349E-05 | 2.61294 | 52 |
| 5000 | .625 | 3.58299E-05 | 3.25797 | 52 |
| 6000 | .515625 | 4.27133E-05 | 3.88575 | 52 |
| 7000 | .445312 | 5.02969E-05 | 4.57435 | 52 |
| 8000 | .390625 | 5.74703E-05 | 5.22593 | 52 |
| 9000 | .34375 | 6.43090E-05 | 5.85075 | 52 |
| 10000 | .3125 | 7.16686E-05 | 6.515 | 52 |
| 11000 | .28125 | 7.84257E-05 | 7.13294 | 52 |
| 12000 | .257812 | 8.54278E-05 | 7.77161 | 52 |
| 13000 | .238281 | 9.32280E-05 | 8.48166 | 52 |
| 14000 | .222656 | 1.00596E-04 | 9.14885 | 52 |
| 15000 | .207031 | 1.07549E-04 | 9.78301 | 52 |
| 16000 | .195312 | 1.14943E-04 | 10.452 | 52 |
| 17000 | .183594 | 1.21989E-04 | 11.0933 | 52 |
| 18000 | .171875 | 1.28621E-04 | 11.7017 | 52 |
| 19000 | .164062 | 1.36103E-04 | 12.3773 | 52 |
| 20000 | .15625 | 1.43325E-04 | 13.0323 | 52 |
| 21000 | .148437 | 1.50244E-04 | 13.6631 | 52 |
| 22000 | .140625 | 1.55816E-04 | 14.2562 | 52 |
| 23000 | .136719 | 1.64942E-04 | 14.9925 | 52 |
| 24000 | .128906 | 1.70851E-04 | 15.5436 | 52 |
| 25000 | .123047 | 1.78838E-04 | 16.2762 | 51 |

MAXIMUM HOLE LENGTH = 7.05491E-05 IN.

The forward velocity of an artillery projectile is related to the bore diameter (D) and spin rate ($\omega$) by the twist (T) of the rifling.

$$V = \frac{2\pi\omega D}{T} \qquad (3.1.12)$$

The distance traveled by the projectile assuming negligible aerodynamic drag is:

$$X = Vt = \frac{2\pi\omega Dt}{T}$$

Thus,

$$t = \frac{XT}{2\pi\omega D} \qquad (3.1.13)$$

The centrifugal force on a SEOD piston is:

$$F = MR\omega^2 \qquad (3.1.14)$$

The time delay from equation (3.1.3) is:

$$t = \frac{LA}{KB}\sqrt{\frac{\rho A}{2F}}$$

or

$$t = \frac{LA}{\omega KB}\sqrt{\frac{\rho A}{2MR}} \qquad (3.1.15)$$

Where:

$\omega$ = projectile spin ($sec^{-1}$)

M = SEOD effective drive mass ($\frac{lb.sec^2}{in}$)

R = distance of SEOD drive mass center of gravity from spin axis (in)

Since both time delays are proportional to $1/\omega$ the SEOD damping characteristic results in constant turns to arm. This is true even though the distance from the center of drive mass to the spin axes varies during arming providing the angular velocity does not vary appreciably.

### 3.2 SHEARFLOD Safety Setback Device

For many years there has been a desire in the military to render all ammunition drop safe. Specifically, it is highly desirable that all ammunition be designed to withstand a 40' drop onto any surface without the possibility of the fuze becoming armed. The basic problem has been that under such drop conditions the acceleration which the fuze experiences can be of the same magnitude or much greater than that experienced in an actual ballistics environment. An artillery shell dropped onto a 6" steel plate, for example, could experience an acceleration of greater than 20000 g. The difference, of course, is that during a firing the duration of the acceleration is considerably longer. Or stating this another way, the energy change involved in an actual firing is considerably greater than present in a 40' drop.

Most attempts to achieve drop safety have been based upon a simple spring mass system. It is very difficult to provide adequate drop safety in a small space with simple systems of this type. Thus, such devices are often activated by something less than a 40' drop. To overcome the deficiencies of the simple spring mass system, sequential spring mass systems were devised. Such systems differentiate between a short duration and a longer duration acceleration, however, they are generally cumbersome, composed of many parts and relatively expensive to manufacture.

To achieve drop safety for this artillery S & A application, a SHEARFLO dashpot was chosen. This SHEARFLO consists of an accurate piston and cylinder as shown in Breed Corporation Drawing No. 508970. A grease-like compound is placed in the clearance between the piston and cylinder, and during activation of the device the piston moves relative to the cylinder shearing this compound causing a viscous retarding force. When the device is accelerated, the piston begins moving in the cylinder being opposed by a spring and the viscous force. Since the retarding force is a function of the velocity of the pin, the faster one attempts to move this pin, the greater the retarding force. It therefore requires an acceleration of a significant magnitude and duration to cause the piston to travel the full distance in the cylinder. Under drop conditions with a properly designed unit, the piston will move only a very short distance in the cylinder, whereas under typical setback conditions sufficient energy is present to permit the piston to travel to the bottom of the cylinder.

Because the SHEARFLOD therefore requires a larger amount of energy input to become fully activated, it successfully differentiates between a high energy setback situation and a much lower energy drop condition even though the magnitude of the accelerations are the same.

The viscosity of a substance can be defined by the relation:

$$\tau_x = \mu\frac{dU}{dy} \qquad (3.2.1)$$

Where $\mu$ can be a function of U, y, h and T. For the case where the clearance in the region of interest is small compared with the radius, the viscosity is constant, and fully developed flow exists,

$$\frac{dU}{dy} = \frac{U}{h}$$

The shear stress is defined as the force per unit area in the x direction, thus,

$$\tau_x = \frac{F_x}{Rd\theta dx} \qquad (3.2.2)$$

Where:

$h$ = is the local clearance (a function of x and θ)

$F_x$ = the force on the piston in the x direction

$U$ = the velocity of the piston

$R$ = the radius of the piston

$\theta$ = the angular coordinate around the circumference

$x$ = coordinate along the cylinder axis

$y$ = the coordinate perpendicular to the cylinder axis

$T$ = temperature

Substituting these relationships and solving for the force on the piston,

$$F_x = \iint \frac{\mu U}{h} Rd\theta dx$$

This equation can be integrated for centered travel if we assume that the viscosity is independent of X and θ to yield,

$$F = \frac{2\pi\mu URL}{\bar{h}} \qquad (3.3.3)$$

This is as far as analysis can be taken at this time. The relation relating the viscosity to the shear rate, clearance, temperature, etc., must be determined experimentally for each substance to be used.

In general, in order to obtain a device whose time delay is relatively constant over the military temperature range the piston is chosen from a material having a significantly higher thermal coefficient of expansion than the cylinder. Once materials for the piston and cylinder have been chosen and once the cylinder internal diameter is picked, the diameter of the piston can be determined for optimum temperature compensation for a given fluid. For a device the size of the safety setback device, very little temperature compensation can be achieved in this way. Experimental results have indicated, however, that the variation in time delay is not as severe as would be expected for the SPEARFLOD used in this contract.

## 3.3 Comparison of Spring-mass and Viscous Damping Setback Systems

### 3.3.1 Analysis of Spring-mass System

A summation of the forces on the mass from Figure 3.3.1 yields:

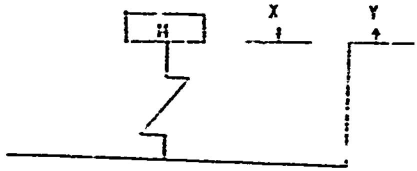



Figure 3.3.1

$$\Sigma F = -M\ddot{X} + F_o + K(Y-X) = 0 \qquad (3.3.1)$$

Where:

$M$ = Mass of setback pin

$X$ = Absolute displacement of setback pin

$Y$ = Absolute displacement of projectile

$K$ = Spring constant

$F_o$ = Initial spring compression force

Putting this equation into standard form,

$$\ddot{X} + \frac{K}{M}X = +\frac{F_o}{M} + \frac{K}{M}Y \qquad (3.3.2)$$

If we assume a constant acceleration of the projectile

$$Y = 1/2\, at^2 \qquad (3.3.3)$$

Where:

$a$ = projectile acceleration

$t$ = time

Thus:

$$\ddot{X} + \frac{K}{M}X = \frac{F_o}{M} + \frac{Ka}{2M}t^2 \qquad (3.3.4)$$

The solution of equation (3.3.4) is composed of a homogeneous and particular part,

$$X = X_H + X_P \qquad (3.3.5)$$

Which can be found in the usual manner to be:

$$X_H = A_1 \cos\sqrt{\frac{K}{M}}\ t + A_2 \sin\sqrt{\frac{K}{M}}\ t$$

and

$$X_p = 1/2\ a\ t^2 - \left(\frac{Ma-F_0}{K}\right) \qquad (3.3.7)$$

The constants $A_1$ and $A_2$ can be obtained from the initial conditions:

$$X = 0, \dot{X} = 0 \text{ at } t = 0$$

To give

$$X = 1/2\ a\ t^2 - \frac{(Ma-F_0)}{K}\left(1 - \cos\sqrt{\frac{K}{M}}t\right) \qquad (3.3.8)$$

The relative motion of the pin is therefore:

$$(Y-X) = \left(\frac{Ma-F_0}{K}\right)\left(1 - \cos\sqrt{\frac{K}{M}}t\right) \qquad (3.3.9)$$

The motion of a spring mass system can be simplified for the case of a constant spring force and a step function acceleration[1]. For this case equation (3.3.1) becomes:

$$M\ddot{X} = F_0 \qquad (3.3.10)$$

and

$$\ddot{Y} = A \qquad (3.3.11)$$

Integrating and applying the initial conditions:

$$\dot{X} = F\ t + C$$

$$\dot{X} = -V \text{ at } t=0$$

[1]This analysis follows a suggestion by David Overman and William Balderson of Harry Diamond Laboratories.

$$\dot{X} = F\,t - V \qquad (3.3.12)$$

$$X = 1/2\,F\,t^2 - Vt \qquad (3.3.13)$$

$$\dot{Y} = A\,t + C$$

$$\dot{Y} = V \text{ at } t = 0$$

$$\left.\begin{aligned} \dot{Y} &= A\,t - V & 0 \le t \le t_0 \\ \dot{Y} &= 0 & t_0 \le t \end{aligned}\right\} \qquad (3.3.14)$$

$$\left.\begin{aligned} Y &= 1/2\,A\,t^2 - V\,t & 0 \le t \le t_0 \\ Y &= 1/2\,A\,t_0^2 - V\,t_0 & t_0 \le t \end{aligned}\right\} \qquad (3.3.15)$$

Where:

$A$ = Acceleration of projectile

$t_0$ = Time to stop projectile

$V$ = Initial velocity

$F = \dfrac{F_0}{M}$

When the pin has traveled its maximum distance its velocity is zero. This would always occur after $t_0$ providing the acceleration exceeds the bias value. Then since:

$$\dot{Y} = 0 = A\,t_0 - V \qquad (t = t_0)$$

$$V = A\,t_0 \qquad (3.3.16)$$

and,

$$\dot{X} = 0 = -V + Ft_1$$

Thus,

$$t_1 = \frac{A}{F} t_0 \qquad (3.3.17)$$

Where:

$t_1$ = Time at maximum pin travel

The travel of the pin from equations (3.3.13) and (3.3.14) is then:

$$Y-X=1/2\ A\ t_0^2 - V\ t_0 - 1/2\ Ft_1^2 = Vt_1 \qquad (3.3.18)$$

Substituting equations (3.3.16) and (3.3.17) into (3.3.18) and simplifying yields:

$$Z = \frac{V^2}{2} \left(\frac{1}{F} - \frac{1}{A}\right) \qquad (3.3.19)$$

3.3.2 Analysis of Viscous Damping Setback System

Using the same notation as before but neglecting the spring force since the spring is now chosen to provide a slow return time for the piston and will be considerably lighter than the viscous damping force, yields:

$$\Sigma F = -M\ddot{X} - D(\dot{X} - \dot{Y}) = 0 \qquad (3.3.20)$$

Where:

D = Linear viscous damping coefficient

Rearranging gives:

$$\ddot{X} + \frac{D}{H}\dot{X} = \frac{D}{H}\dot{Y} \tag{3.3.21}$$

If we assume a constant acceleration

$$\dot{Y} = at \tag{3.3.22}$$

Thus,

$$\ddot{X} + \frac{D}{H}\dot{X} = \frac{Da}{H}t \tag{3.3.23}$$

Again the homogeneous and particular solution can be found in the conventional manner to yield:

$$X_H = A_1 e^{-\frac{D}{H}t} + A_2 \tag{3.3.24}$$

$$X_p = 1/2\ at^2 - \frac{aH}{D}t \tag{3.3.25}$$

Using the same initial conditions as above gives the complete solution:

$$X = 1/2\ at^2 - \frac{aH}{D}t - a\frac{H^2}{D^2}e^{-\frac{D}{H}t} \tag{3.3.26}$$

The relative motion of the pin is therefore:

$$Z = Y - X$$

$$Z = +\frac{aH}{D}t + a\frac{H^2}{D^2}e^{-\frac{D}{H}t} \tag{3.3.27}$$

Since $(Y-X)<1$ and for any reasonable drop or firing pulse $at>>1$, $\frac{H}{D} << 1$* and the second term can be neglected, thus

$$Z = \frac{aH}{D} t \qquad (3.3.28)$$

### 3.3.3 Discussion

Comparing equation (3.3.19) to equation (3.3.28) it can be seen that for the pure spring mass system the travel of the mass is not only a function of the velocity change but also of the acceleration. For the SHEARFLOD system, however, the travel is a function of the velocity change only. In addition, once the bias acceleration is chosen, the travel of the mass is fixed for the spring mass system for a given acceleration whereas in the SHEARFLOD system there is no such limitation imposed on the design.

---

*To get an order of magnitude approximation assume $(Y-X) = 1$ inch and $a = 5 \times 10^5$ in/sec$^2$. If the first and second terms on the right are equal, then

$$\frac{D}{H} t = .567$$

or

$$t = .567 \frac{H}{D}$$

Thus,

$$1 = 1.134\, a \left(\frac{H}{D}\right)^2$$

Therefore

$$\frac{H}{D} = 1.33 \times 10^{-3} \text{ sec}$$

Thus

$$\frac{H}{D} << 1$$

and the second term can be neglected.

## 4. Summary of Work Accomplished Under Contract

### 4.1 Scope

The scope of this contract was to explore the feasibility of a safety and arming device for use in artillery fuzes. This device was to use dashpots to provide such functions as arming delay and was to include a dud clean up feature. It was to meet out-of-line safety, safe separation, handling, environmental resistance, physical shape, explosive train, dud clean-up, and other performance requirements as delineated in the statement of work. The contract involved the construction of 85 units to go through two test programs as depicted on Charts 1 and 2. During the course of the contract substantial modifications were made in the proposed design of the S & A device which had the effect of significantly improving its reliability and safety, and significantly reducing manufacturing costs.

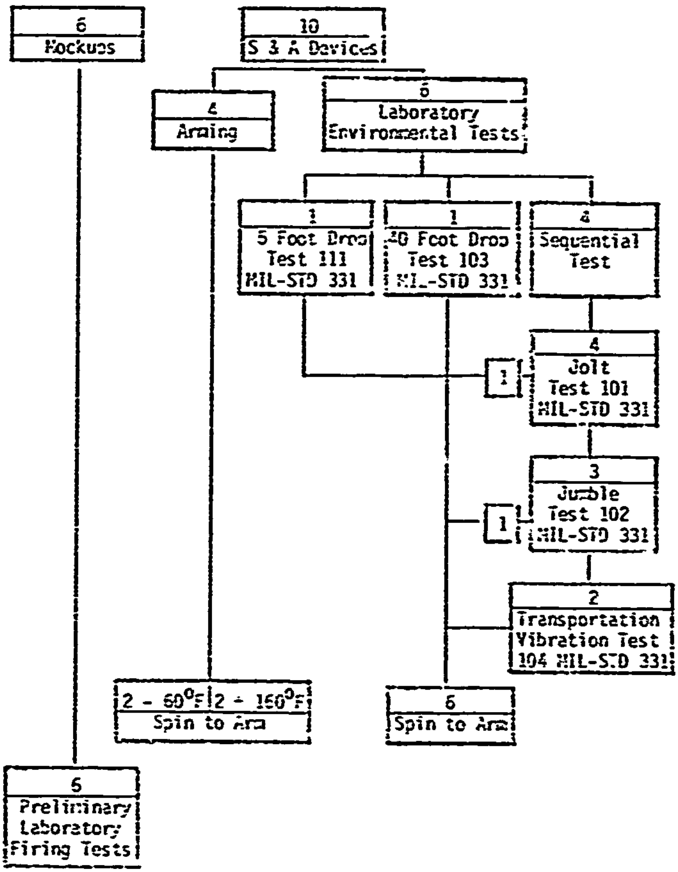



CHART 1

PRELIMINARY TEST PLAN

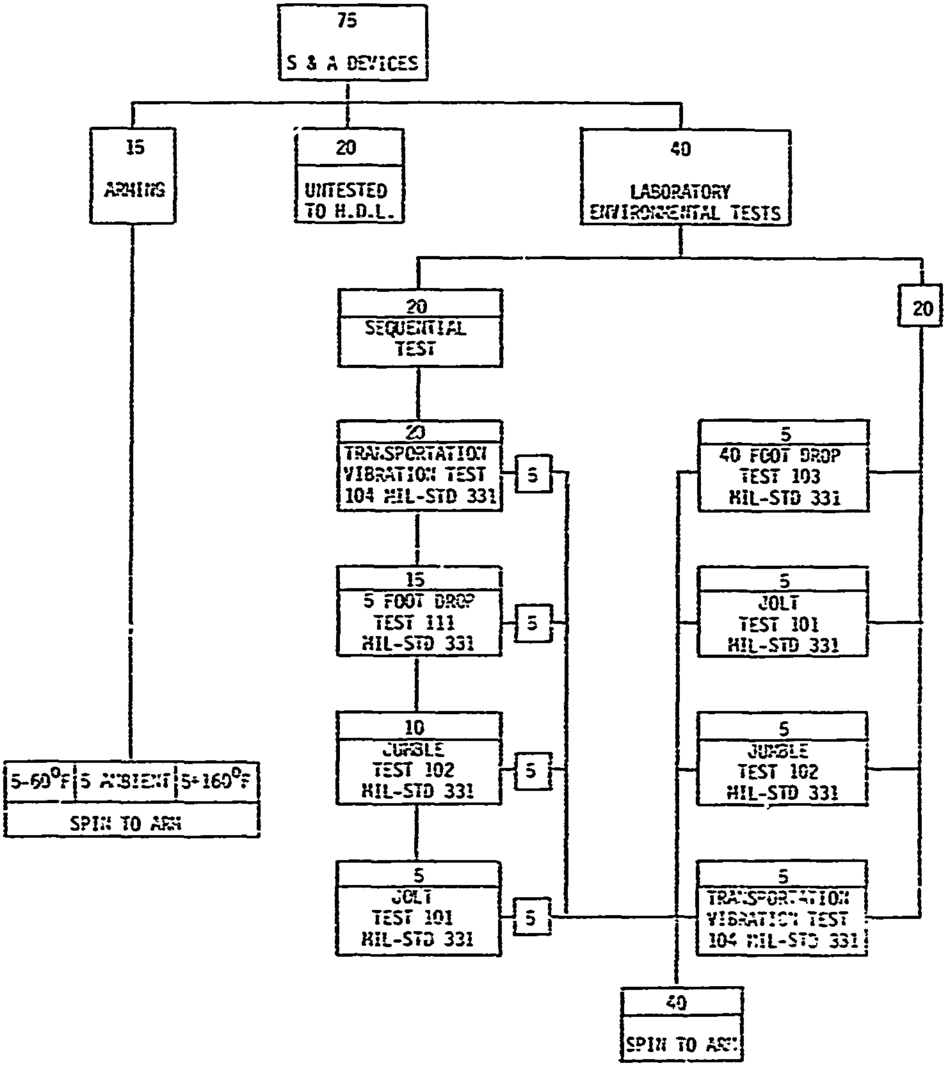



CHART 2

MAIN TEST PLAN

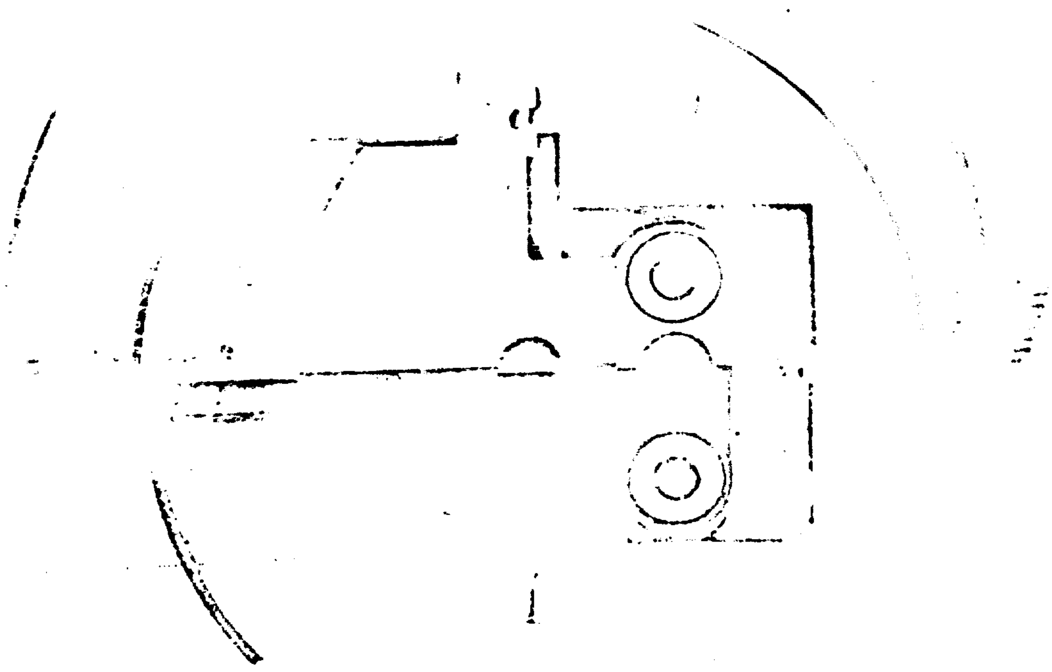
4.2 Pre-contract Modifications

The original design proposed is shown in Drawing 508600. Prior to the beginning of this contract several changes were made at the suggestion of HDL engineers. In particular, a reservation concerning the adequacy of an .080 inch wide barrier in the explosive train of the original design was removed through a redesign which placed the SECO timer in the main moving mass wherein the timer became the barrier in the explosive train. This design modification had the further advantage that the fragile prongs on the sliding mass of the original design could be eliminated which removed concern that these prongs might elastically deform in such a way as to become a significant source of friction.

An additional concern revolved around the setback and spin sensing pins of the original design. This led to the incorporation of the SHEARFLOD setback sensor described above.

4.3 Early Design Changes

After the contract was awarded, a meeting was held at Harry Diamond Laboratories wherein the possibility of using an HDL developed super-quick detonator assembly was discussed. This is a system wherein a detonator is held in a small slider spring loaded away from a firing pin. Upon impact the mass of the slider propels the detonator into the fixed firing pin.



This discussion led to the idea of using a delay detonator in a similar manner and eventually resulted in the two redundant delay detonator systems now incorporated in the final design. The second delay detonator was incorporated to provide redundancy when the fuze is operated in the delay mode.

At this same visit it was suggested that, if possible, the size of the S & A should be reduced so that when used in a module configuration it would fit into a smaller cavity than the M125A1 booster. As a result the size of the S & A was reduced, however, subsequently it was learned that even a further size reduction was desired. This, it is felt, cannot easily be done with the design configuration of the present S & A.

Throughout the contract period, but more specifically near the beginning of the effort, a substantial amount of effort went into reducing the complexity of the S & A. The LADD self-destruct system was replaced by the two impact sensitive delay detonators as described above. In addition, a one piece aluminum body replaced the original two piece system originally proposed. The slider weight was redesigned to give it a simpler and more symmetrical shape making it possible to be produced as an aluminum extrusion rather than a more expensive zinc die casting. The original 45° combination spin setback lock weight was replaced by two spin sensing locks which provide out-of-line locking and one SHEARFLOD setback pin.

A substantial amount of work went into finding an appropriate seal which would stand up under temperature cycling as well as the rough handling tests. Modifications in this area continued to nearly the end of the contract.

## 4.4 Explosive Tests

During the second month of the contract    mockups were used to perform the preliminary explosive safety tests of Chart 1. In the out-of-line condition it was found that initiation of the superquick detonator also resulted in initiation of the two delay detonators. However, even with all three explosive elements going off, there appeared to be no damage or deformation to the output leads. One unit was set off with the output from the detonators as nearly in-line with the RDX leads as possible without overlapping them. When the detonators were set off they failed to set off the RDX leads. However, upon inspection it was noted that the lead cup tops were bowed slightly. The final unit was set off in-line to prove out the explosive train. The unit functioned as planned with all three leads again going off as determined by a steel witness plate.

Nine additional explosive tests were run at Picatinny Arsenal and were not included on the test plan. These tests involved mockup units and were conducted to determine whether the delay detonators would set off the superquick and thus bypass the delay time and also what the duration of the delay time was. During this period these detonators were under development at Picatinny Arsenal. The initial group of five units which were tested produced erratic time results but in no case did the delay detonator set off the super-quick detonator. The final four units were tested using a new lot of detonators with significantly improved results, however, 3 out of the 4 units were not within the 50 ±20 millisecond delay time. Since these tests were run we have had assurance from Picatinny Arsenal that the detonators can now be obtained which fall into the specified tolerance range.

4.5 Tolerance Study and Initial Time Tests

During the third month of the contract a 10 to 1 layout of the entire design was made. All of the major parts were studied and changes in dimensions and tolerance made where necessary so that no combination of manufacturing tolerances could effect the reliability and safety of the S & A. These tolerances are reflected on the final prints.

Initially the SEOD piston was first made and then ground to size. However, due to the small size of the part, roundness was difficult to maintain and a condition of 3 point lobing existed. This problem was solved by grinding the piston in longer lengths then cutting them to the required length.

During this contract an automatic indexing test fixture was constructed to permit static load testing of the SEOD assembly under computer control in temperature bands from -65°F to 160°F. A photograph of this test fixture is shown in Figure 4.1. Test results run on this automatic static high load SEOD test fixture appear in Table 4.1. The force applied to the SEOD piston corresponds to 13,000 to 16,000 rpm. An .008 inch orifice size was used except for No. 12 which had an .0018" orifice and No. 15 which had an unknown orifice size. The piston/cylinder clearance was between .000250 and .000300 inches.

After considerable testing a diametral clearance of .000250 to .000300 inches seemed to be the best tradeoff between tolerance control on the one hand and excessive leakage between the piston and cylinder on the other. Test results for several SEODs are shown in Table 4.1. These SEODs utilize five centistoke silicone fluid as did all subsequent tests.

TABLE 4.1 - STATIC LOAD SEOD RESULTS

Time in Milliseconds at Temperature

| SEOD No. | -65°F | -35°F | Ambient | 160°F |
|---|---|---|---|---|
| 10 | 68, 67 | - | 50, 50, 54, 53, 56, 53, 53, 55 | 45 |
| 11 | 95, 95 | 90, 89, 85 | 88, 88, 87, 86, 88, 87, 89 | 78 |
| 12 | 597, 478 | 423 | 395, 387, 438, 384, 371 | - |
| 13 | - | 78 | 77, 88, 79, 78, 79, 77, 77, 75 | 71 |
| 14 | 95, 124 | 78, 75 | 77, 77, 79, 92, 78 | 77 |
| 15 | 92 | 82, 107 | 75, 76, 77, 76, 77, 79 | - |
| 16 | - | 171, 173 | 158, 163, 164, 159, 156 | 133 |
| 17 | 87, 79 | 79, 86, 77 | 78, 78, 78, 77, 79, 78, 79 | 70 |
| 18 | 125, 80 | 82, 85, 80 | 80, 80, 80, 79, 81, 79 | - |
| 19 | 94, 90 | 85, 90, 83 | 85, 83, 86, 85, 83, 84 | - |
| 20 | - | 155, 85 | 75, 73, 73, 73, 73, 76, 77, 78 | - |
| 21 | 80, 76 | 79, 71, 69 | 60, 61, 61, 63, 61, 60 | - |

4.6 Centrifuge Tests

In order to test the operation of the S & A device under varying spin rates, a centrifuge (spinner) was built based upon a Pope grinding motor. This centrifuge was constructed after consultation with HDL and observation of a similar centrifuge in operation there. The centrifuge worked well initially from 1000 to 13,000 rpm, however, considerable debugging was required before the higher speeds of 25,000 rpm could be reached. The main problem revolved around vibrations due to unbalance in the fixturing and the fact that the center of gravity of the S & A shifts during normal operation of the device. A photograph of the centrifuge is shown in Figure 4.2.

In Table 4.2 results of the turns-to-arm versus rpm are presented. The results of SEOD No. 22 are plotted in Figure 4.3. The turns-to-arm for these cases were slightly low due to the orifice being somewhat too large.

The static SEOD load tests (Table 4.1) were conducted without the foil seal installed. The SEOD was tested in a vertical axis eliminating the need for a seal. The centrifuge tests (Table 4.2) were run without a crimped seal. A series of tests were conducted to verify that the SEOD operated identically with and without the seal. The foil seals were not necessary due to the insignificant fluid leakage between filling,

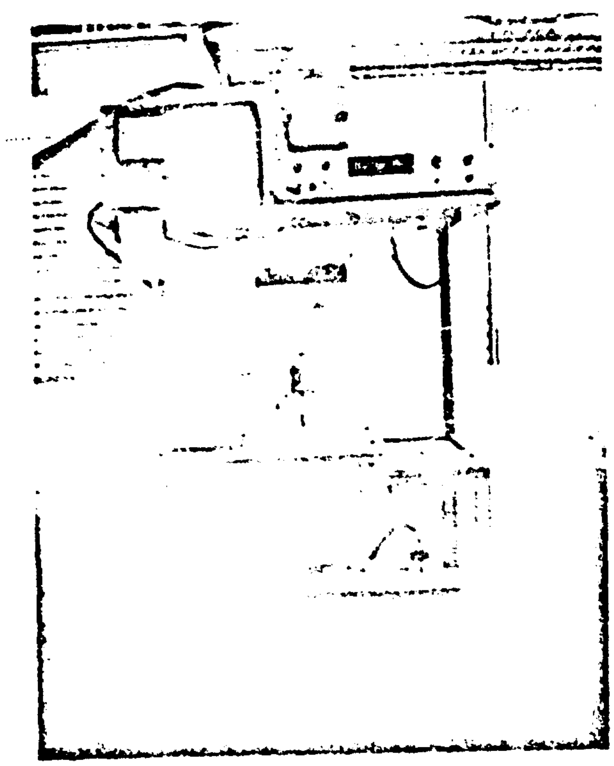


Figure 4.2

TABLE 4.2 - CENTRIFUGE SPIN TESTS

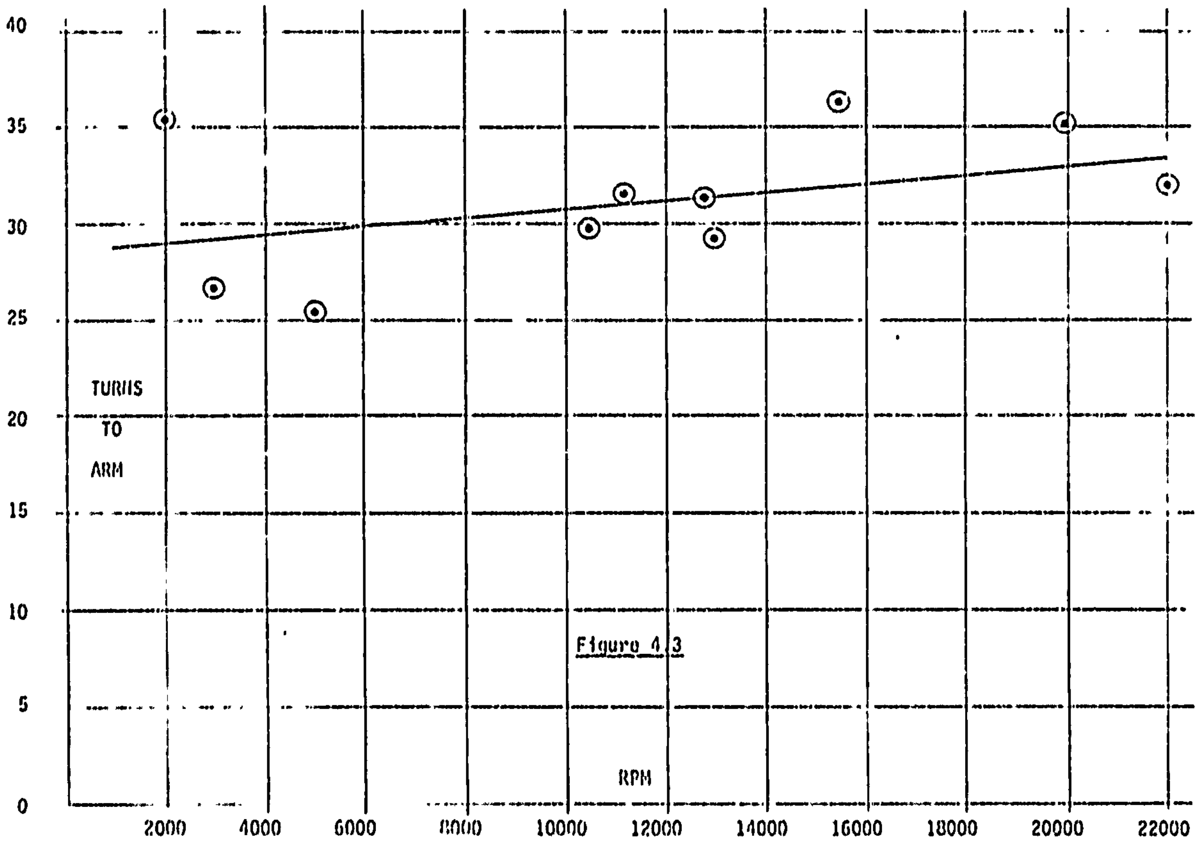
| SEOD No. | Clearance x $10^6$ | Orifice Diameter x $10^3$ | Temp. °F | RPM | Turns to Arm | Mean |
|---|---|---|---|---|---|---|
| 11 | 350 | 7 | Ambient | 3,000 | 18.7, 17.9, 22.3, 27.9 | |
| 16 | 325 | 6.5 | Ambient | 2,700 | 37.7, 37.6, 37.2, | |
| | | | | 3,300 | 37.1 | |
| | | | | 7,500 | 30.7 | |
| | | | | 12,500 | 23.7 | |
| | | | | 11,500 | 16.1, 27.1, 26.0, 27.0 | |
| 16X | 275 | 6.5 | Ambient | 2,900 | 34.3, 35.4, 35.8, 37.0, 36.5, 35.7 | |
| | | | -50°F | 2,900 | 38.2, 38.2, 34.3 | |
| | | | Ambient | 3,500 | 36.4, 35.4 | |
| | | | | 4,000 | 93.8, 34.4 | |
| | | | | 5,000 | 34.0, 32.7 | |
| | | | | 6,000 | 31.4, 31.8 | |
| | | | | 7,000 | 34.5, 27.0, 31.2 | |
| | | | | 8,000 | 29.4, 28.5 | |
| | | | | 10,000 | 27.9, 28.1 | |
| | | | | 12,000 | 36.4, 33.6 | |
| | | | | 13,000 | 21.4, 24.9, 24.2 | |
| 21 | 200 | 4.5 | Ambient | 2,900 | 51.6, 51.1, 56,3, 52.3 | |
| | | | | 10,000 | 89.1, 43.5, 47.5, 45.7 | |
| 21X | 275 | 4.5 | Ambient | 2,900 | 48.7, 47.9, 50.6, 49.5 | |
| | | | | 10,000 | 45.1, 43.4 43.8, 45.6 | |
| 22 | | | Ambient | 2,000 | 34.6, 31.8 40.4 | 35.6 |
| | | | | 3,000 | 26.0, 28.0, 25.4, 26.1 | 26.4 |
| | | | | 5,000 | 28.0, 24.8, 24.3, 24.4 | 25.4 |
| | | | | 10,000 | 29.8 | 29.8 |
| | | | | 11,200 | 26.8, 35.2 | 31.5 |
| | | | | 12,800 | 31.1, 31.4 | 31.3 |
| | | | | 13,000 | 28.7 | 28.7 |
| | | | | 15,500 | 36.4 | 36.4 |
| | | | | 20,000 | 36.4, 34.3 | 35.3 |
| | | | | 22,000 | 32.1 | 32.1 |

placing into the spin fixture and initiating spin.

Refilling the SEOD was accomplished by removing the piston, filling with filtered fluid and replacing the piston. Once the retaining washer has been crimped to the SEOD cylinder the cylinder may not be used again. In early environmental tests many SEODs were used over again. These SEODS were not crimped. In these cases the retaining washer was held against the foil disc and SEOD cylinder by a washer fitting around the retaining washer and threaded into the slider weight.

4.7 Preliminary Test Plan Results - Chart 1

The results of the four units tested for arming according to Chart 1 are shown in Table 4.3. All four were tested at -65$^{O}$F ambient and +160$^{O}$F. The results of the six laboratory environmental test units from Chart 1 are as follows. The five foot drop test was conducted according to MIL-STD-331 Test 111 except that all drops were made at 7 feet instead of 5 feet. The S & A was screwed into a 3" long section of an 81 mm. round and the test unit was dropped onto a steel plate several times in each of the five orientations. When dropping the fuze in the horizontal plane emphasis was placed on aligning the slider in a vertical position so as to put the greatest load


40
35
30
25
20
15
10
5
0
TURNS
TO
ARM
Figure 4.3
RPM
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000

on the spin lock pins. In the horizontal plane after repeated drops the material around the detent of the slider started to bend. The unit remained safe and armed properly when spun. Nevertheless, the slider was strengthened to eliminate this condition.

The 40 foot drop test was conducted according to MIL-STD-331 Test 103. The S & A device was screwed into an MK-30 fuze and then into a 3" length of an 81 mm. mortar case. After five 40 foot drop the unit was removed from the mortar case, put in a centrifuge and spun. The unit armed in 32.8 turns, after the drops as compared to an average of 32.2 turns before the drops.

The jolt test of Chart 1 was conducted in accordance with MIL-STD-331 Test 101. The test plan of Chart 1 was modified somewhat to permit the simultaneous running of these preliminary tests. One unit was jolt tested at Picatinny Arsenal. A hairline crack developed in the foil which permitted the fluid to leak out. After the jolt test the S & A functioned when spun in 0.6 turns. A similar problem occurred in the jumble test which was conducted on one unit in accordance with MIL-STD-331 Test 102. The unit armed in .5 turns.

TABLE 4.3

Arming Tests at Different Temperatures - Chart 1

Four Units 3,000 RPM

| S & A | -60°F | Ambient | +160°F | % Variation Hot to Cold |
|---|---|---|---|---|
| 6 | 40.0 | 42.9, 41.8 | 43.1 | - 9% |
| 7 | 23.5 | 20.6, 21.3 | 22.6 | + 5% |
| 8 | 32.9 | 28.6, 30.9 | 31.8 | + 3% |
| 9 | 34.1 | 32.6, 32.1 | 30.3 | +13% |

The transportation vibration test was conducted in accordance with MIL-STD-331 Test 104 procedure I. Four S & A units were vibrated; two having a new seal designed after the previous jolt and jumble tests and two with the old seal. The new seal differed from the old seal in that a modified sealing washer having a smaller internal diameter was used. One of the SEDDs having the old sealing system leaked The test results for the four units vibrated are shown in Table 4.4. After the vibration tests all units were armed then taken apart and inspected. All parts of the S & A were intact and with the exception of the one unit that leaked, no signs of degradation of any of the parts were evident. As a result of these tests several modifications were made to various parts of the S & A. All of these modifications are depicted in the final set of drawings.

TABLE 4.4

Transportation Vibration Tests - Chart 1

| S & A | Turns-to-arm Before Transportation Vibration | Turns-to-arm After Transportation Vibration |
|---|---|---|
| 04 | 38.3, 39.3 | 41.1 |
| 05 | 54.8, 49.5 | 55.8 |
| 06 | 40.6, 43.7 | .7* |
| 07 | 23.8, 22.6 | 25.1 |

*Foil sealing disc fractured and SEOD leaked.

### 4.8 Main Test Plan Results - Chart 2

The results of the more extensive testing as depicted in Chart 2 appear in Tables 4.5 through 4.13. The fifteen units which were to be checked at -60°, ambient and +160° for turns-to-arm were actually put through a far more extensive test than called for on the test plan. Instead of running just 5 units at each of the temperatures, it was decided to run all 15 units through each of the temperatures and also at three different spin rates. The results appear in Table 4.5. A few data points are missing due to equipment problems wherein the turns-to-arm did not record. Two units appear with a rather small number of turns-to-arm. In both cases this was due to problems with the foil sealing disc. In the case of Fuze No. 10 run at 160° the foil had been misinstalled leaving a gap through which the fluid could leak out. In the case of

Fuze No. 10 at $-65^{o}$ the foil had a defect permitting the fluid to leak out.

The failure of the foil seal in several of the tests has highlighted this potential problem area. This is important since loss of the fluid would result in a loss of most of the arming delay. A procedure must therefore be included in the production process to verify fluid presence. This could be done on an automatic spin fixture which would time the SEOD, then shift the entire assembly so that centrifugal force would return the piston to its starting position creating a considerable pressure (such as 100 psi) followed by a retiming. A comparison of the first and second times would then be a check of fluid leakage. A simple inertial mechanism could also be incorporated which would lock the slider in the safe position if its initial velocity exceeded a given value indicating that the fluid had escaped.*

The two places where this timer could be expected to deviate from a constant turns-to-arm, if at all, would be at low spin rates and cold temperature where viscous effects would take place in the orifice and at high spin rates and high temperature where the leakage in the clearance between



*This idea was suggested by William Balderson of Harry Diamond Laboratories.

the piston and cylinder would cause the turns-to-arm to decrease. From Table 4.5 an increase in the turns-to-arm did in fact take place at the low spin rates between ambient and -65$^0$. However, between ambient and -40$^0$ there is very little shift. The second condition did not occur, however, for the spin rates tested. Very little shift occurred in the turns-to-arm in going from ambient to +160$^0$ at the high spin rates. The highest spin rate used for this test was 12,000 to 13,000 rpm. Since projectiles spin as high as 25,000 to 30,000 rpm it would be desirable to run some tests up at this area. However, the fact that no significant change took place at 12,000 to 13,000 rpm indicates that the leakage at this spin rate was small. Thus even though this leakage would increase by a factor of approximately 4 at 25,000 a significant change in the turns to arm should not take place at this higher rpm point.

Tables 4.6 to 4.9 shows the results of the sequential test units. From these results it can be seen that no appreciable change occurred during transportation vibration tests or the 5 foot drop tests (actually run at 7 feet). However, during the jumble test wood chips from the jumble box apparently got into the fuze through the open lead holes (tests were run without leads) and punctured the foil seal permitting the fluid to leak out. Spin to arm tests therefore could not be run on the jumble or the jolt units. During the jolt test

TABLE 4.5

TEMPERATURE SPIN TESTS - CHART 2

Turns-to-arm (Spin Rate 2000-2500)

| SEOD No. | $-65^{0}F$ | $-40^{0}F$ | Ambient | $+160^{0}F$ |
|---|---|---|---|---|
| 6 | 66.2 | 50.7 | 44.0 | 48.3 |
| 7 | 61.5, 59.5 | 51.6 | 46.1 | 52.7 |
| 8 | 55.0, 61.8 | 52.8 | 45.8 | 54.4 |
| 9 | 61.3, 62.6 | 54.1 | 47.7 | 52.4 |
| 10 | 57.7, 57.5 | 49.3 | 45.6 | 44.7 |
| 11 | 63.6, 59.1 | 49.2 | 47.6 | 52.4 |
| 12 | 54.8, 51.0 | 50.0 | 46.0 | 46.9 |
| 13 | - 67.6 | 53.4 | 45.8 | 58.9 |
| 14 | 61.0, 59.8 | 51.6 | 47.9 | - |
| 15 | 66.6, 59.0 | 52.8 | 46.4 | 47.0 |
| 16 | - 56.9 | 50.9 | 46.2 | 47.7 |
| 17 | 73.4, 60.6 | 49.4 | 44.7 | 49.9 |
| 18 | 57.3, 53.2 | 52.4 | 48.1 | 48.4 |
| 19 | 49.6, 53.6 | 47.0 | 39.9 | - |
| 20 | 64.4, 57.0 | 50.8 | 44.6 | - |
| Mean | 59.69 | 51.07 | 45.76 | 50.31 |
| Std. Dev. | 5.3 | 1.9 | 2.0 | 4.0 |

Turns-to-arm (Spin Rate 6500-7000)

| SEOD No. | $-65^{0}F$ | $-40^{0}F$ | Ambient | $+160^{0}F$ |
|---|---|---|---|---|
| 6 | 42.9 | - | 46.2 | 45.1 |
| 7 | 44.4 | - | 42.9 | 46.2 |
| 8 | 43.0 | - | 45.3 | 44.0 |
| 9 | 50.0 | - | 49.2 | 49.7 |
| 10 | 39.2 | - | 42.8 | 45.4 |
| 11 | 41.9 | - | 42.9 | 43.9 |
| 12 | 45.5 | - | 47.9 | 50.5 |
| 13 | 48.3 | - | 42.3 | 41.6 |
| 14 | 41.5 | - | 45.1 | 47.7 |
| 15 | 47.2 | - | 46.8 | 49.9 |
| 16 | 46.9 | - | 43.9 | 47.9 |
| 17 | 47.0 | - | 45.6 | 43.6 |
| 18 | 47.9 | - | 49.9 | 52.8 |
| 19 | 44.3 | - | 42.4 | 45.9 |
| 20 | 44.8 | - | 41.6 | 47.9 |
| Mean | 45.00 | - | 45.00 | 46.81 |
| Std. Dev. | 2.95 | - | 2.6 | 3.05 |

TABLE 4.5 (Continued)

Turns-to-arm (Spin Rate 12,000 - 13,000)

| SECO No. | -65°F | -40°F | Ambient | +160°F |
|---|---|---|---|---|
| 6 | 45.7 | - | 45.0 | 46.0 |
| 7 | 49.8 | - | 47.6 | 44.0 |
| 8 | 50.0 | - | 49.9 | 56.6 |
| 9 | 46.6 | - | 47.9 | 51.2 |
| 10 | 53.3 | - | 48.2 | 11.2* |
| 11 | 43.1 | - | 45.3 | 48.7 |
| 12 | 50.8 | - | 45.2 | 44.7 |
| 13 | 41.2 | - | 43.7 | 52.1 |
| 14 | 55.6 | - | 50.5 | 53.5 |
| 15 | 20.4 | - | 46.0 | 48.6 |
| 16 | 42.8 | - | 43.9 | 47.5 |
| 17 | 48.4 | - | 44.4 | 43.4 |
| 18 | 52.5 | - | 47.5 | 46.9 |
| 19 | - | - | - | 48.5 |
| 20 | 49.8 | - | 45.0 | 47.3 |
| Mean | 46.46 | - | 46.46 | 48.55 |
| Std. Dev. | 8.6 | - | 2.17 | 3.59 |

*Eliminated from Mean and Standard Deviation calculations.

run on the non-sequential units to be discussed below, some of the delay detonators had broken through the bottom of the slider. For the units run in the sequential test the bottoms of the delay detonator cavities had been thickened and no breakthroughs occurred thus correcting this problem.

The results for the non-sequential tests are shown in Tables 4.10 through 4.13. From these results it can be seen that no degradation occurred due to 7 foot drop or transportation vibration. For the jolt test as mentioned above, the delay

TABLE 4.6

Sequential Test - Transportation Vibration - Chart 2

Turns-to-arm

| | Before Vibration | After Vibration |
|---|---|---|
| | 44.9 | 45.1 |
| | 42.3 | 44.1 |
| | 39.7 | 45.4 |
| | 44.3 | 43.8 |
| | 43.6 | 42.6 |
| Mean | 42.96 | 44.20 |
| Std. Dev. | 2.06 | 1.11 |

TABLE 4.7

Sequential Test - 7 Foot Drop - Chart 2

Turns-to-arm

| | Before Vibration | After Drop |
|---|---|---|
| | 43.6 | 42.1 |
| | 42.2 | 44.2 |
| | 44.0 | 45.4 |
| | 43.4 | 47.2 |
| | 45.9 | 40.0 |
| Mean | 43.82 | 43.78 |
| Std. Dev. | 1.34 | 2.81 |

TABLE 4.8

Sequential Test - Jumble - Chart 2

Turns-to-arm

| | Before Vibration | After Jumble |
|---|---|---|
| | 47.2 | Wood chips punctured foils. |
| | 44.6 | All units less than 1 turn-to-arm. |
| | 44.7 | |
| | 47.3 | |
| | 45.1 | |
| Mean | 45.78 | |
| Std. Dev. | 1.36 | |

TABLE 4.9

Sequential Test - Jolt - Chart 2

Turns-to-arm

| | Before Vibration | After Jolt |
|---|---|---|
| | 44.7 | Foils broken in jumble test. |
| | 46.2 | All units less than 1 turn-to-arm. |
| | 44.6 | |
| | 47.7 | |
| | 44.5 | |
| Mean | 45.54 | |
| Std. Dev. | 1.39 | |

detonators broke through the bottom of the slider and into the blast cavity locking the slider so that arming could not occur. This was corrected for the sequential tests as mentioned above. In the case of the jumble test the three lead cup holes in the bottom of the fuze were sealed with a piece of adhesive backed aluminum foil. This prevented wood chips from the jumble box from getting into the inside of the fuze and thus none of the foils were punctured by wood chips. One unit, however, did partially arm due to the centrifugal locks coming out and permitting the slider to move sufficiently for the foil to break and some of this fluid to leak out and partial arming occurred. None of these tests were run with the SHEARFLOD setback pin assembled. If this pin had been included it would necessitate disassembling the unit, removing the SHEARFLOD pin and reassembling it prior to spin testing. Had the SHEARFLOD pin been in place this single unit probably would not have partially armed during the jumble test.

To summarize, a few problems arose during the MIL-STD tests. However, in each case it appears the problem can be easily corrected.

This completes the analysis of the 75 S & A devices according to test plan of Chart 2. Twenty units were sent to HDL to be fired for different guns as per the HDL test plan.

TABLE 4.10

7 Foot Drop Test - Chart 2

Turns-to-arm

| | Before Drop | After Drop |
|---|---|---|
| | 47.7 | 46.6 |
| | 44.5 | 44.5 |
| | 46.5 | 43.9 |
| | 44.0 | 46.1 |
| | 44.3 | 63.8 |
| Mean | 45.40 | 48.98 |
| Std. Dev. | 1.62 | 8.36 |

TABLE 4.11

Jolt Test - Chart 2

Turns-to-arm

| | Before Jolt | After Jolt |
|---|---|---|
| | 41.7 | * |
| | 41.3 | 42.8 |
| | 42.4 | * |
| | 42.1 | * |
| | 44.0 | * |
| Mean | 42.3 | |
| Std. Dev. | 1.04 | |

*Delay detonators broke through slider bottom jamming slider.

TABLE 4.12

Jumble Test - Chart 2

Turns-to-arm

| | Before Jumble | After Jumble |
|---|---|---|
| | 48.7 | Unit partially armed during jumble |
| | 46.2 | 43.2 |
| | 48.1 | 41.6 |
| | 46.0 | 41.5 |
| | 46.3 | 43.1 |
| Mean | 47.06 | 42.35 |
| Std. Dev. | 1.25 | .925 |

TABLE 4.13

Transportation Vibration Test - Chart 2

Turns-to-arm

| | Before Vibration | After Vibration |
|---|---|---|
| | 42.7 | 41.2 |
| | 42.0 | 42.3 |
| | 44.0 | 45.4 |
| | 45.6 | 40.9 |
| | 45.8 | 42.9 |
| Mean | 44.02 | 42.54 |
| Std. Dev. | 1.69 | 1.79 |

Preliminary to the firing of the 20 fuzes, nine S & A units were fired for background information. For the first firing three S & A units were used without the SHEARFLOD setback pin. All three armed. For the second firing the setback pin was provided but without the compound between the pin and its cylinder. Once again, all three S & A units armed and were locked in the in-line position by the setback pin. For the third firing the compound was used on the setback pin and once again all three S & A units armed with the SHEARFLOD pin providing in-line locking.

The results of the 20 units delivered to Harry Diamond Laboratories and fired at Aberdeen Proving Ground are presented in Table 4.14. Fifteen boosters armed, two were lost, one did not arm and the remaining two were considered a "no test". The one which did not arm was due to deformation of the shoulder at the bottom of the delay detonator holes which prevented slider motion. Upon inspection the thickness of the shoulder on this unit was found to be below tolerance. The two "no test" units had at least partially armed since the SEOD foil was punctured. In both cases it is believed that full arming occurred and that the impact jolt drove the slider to the out-of-line position. Since this could not be verified they should be eliminated from the test results.

TABLE 4.14

Date Fired: November 8, 1971
Caliber WPN: 105 mm.

| Rd No. | Pressure PSI Chamber | Pressure PSI Base | Setback "G" | Velocity FPS | Spin RPM | Depth in. | Angle deg. | S & A Condition |
|---|---|---|---|---|---|---|---|---|
| 1 | 34,500 | 33,700 | 13,918 | 1,577 | 15,264 | 96 | 0 | A |
| 2 | 35,500 | 34,700 | 14,331 | 1,579 | 15,232 | 139 | 5 | A |
| 3 | 35,500 | 34,700 | 14,331 | 1,580 | 15,288 | 92 | 6 | A |
| 4 | 35,000 | 34,200 | 14,227 | 1,580 | 15,288 | 138 | 0 | A |
| 5 | 34,700 | 33,900 | 14,000 | 1,579 | 15,282 | 118 | 0 | A |

Caliber WPN: 155 mm.

| Rd No. | Pressure PSI Chamber | Pressure PSI Base | Setback "G" | Velocity FPS | Spin RPM | Depth in. | Angle deg. | S & A Condition |
|---|---|---|---|---|---|---|---|---|
| 1 | 6,800 | 6,750 | 2,093 | 658 | 3,108 | 80 | 5 | A |
| 2 | 6,300 | 6,250 | 1,933 | Lost | Lost | 60 | 10 | A |
| 3 | 6,300 | 6,250 | 1,956 | 660 | 3,114 | 114 | 0 | NT |
| 4 | 7,000 | 6,950 | 2,155 | 663 | 3,120 | 48 | 45 | NA |
| 5 | 6,600 | 6,550 | 2,031 | 657 | 3,150 | 72 | 30 | A |

Date Fired: November 11, 1971
Caliber WPN: 175 mm.

| Rd No. | Pressure PSI Chamber | Pressure PSI Base | Setback "G" | Velocity FPS | Spin RPM | Depth in. | Angle deg. | S & A Condition |
|---|---|---|---|---|---|---|---|---|
| 1 | 48,200 | 42,271 | 10,695 | 2,883 | 15,050 | 30 | 85 | Floated A |
| 2 | 50,500 | 44,288 | 11,249 | 2,885 | 15,024 | 30 | 85 | " A |
| 3 | 48,200 | 42,271 | 10,737 | 2,884 | 15,072 | 24 | 90 | " NT |
| 4 | 50,800 | 44,552 | 11,315 | 2,885 | 15,024 | 42 | 45 | " A |
| 5 | 50,400 | 44,200 | 11,183 | 2,817 | 14,724 | 30 | 85 | " Arm |

Caliber WPN: 8 inch

| Rd No. | Pressure PSI Chamber | Pressure PSI Base | Setback "G" | Velocity FPS | Spin RPM | Depth in. | Angle deg. | S & A Condition |
|---|---|---|---|---|---|---|---|---|
| 1 | 9,000 | 8,892 | 2,249 | 808 | 2,910 | Lost | Lost | |
| 2 | 8,800 | 8,694 | 2,191 | 810 | 2,916 | Lost | Lost | |
| 3 | 8,700 | 8,595 | 2,166 | 803 | 2,892 | 132 | 0 | Arm |
| 4 | 8,700 | 8,596 | 2,165 | 802 | 2,885 | 132 | 0 | Arm |
| 5 | 8,600 | 8,497 | 2,141 | 804 | 2,892 | 96 | 30 | Arm |

Angle = degrees from vertical.

### 4.9 SHEARFLOD Setback Pin Test Results

Several tests were additionally run to test the SHEARFLOD setback pin by itself. The test fixtures used were H125E1 booster bodies bored out to accept an aluminum insert which held six SHEARFLOD time delay pins. Three types of setback pins were tested in the first firing with diameters of 1/16, 5/64 and 3/32 inch respectively. The pins were steel and had a diametral clearance of .001 inches to .0015 inches. From these tests the largest pin (3/32) provided the necessary movement when fired in the 75 mm. gun (high g test) but did not move sufficiently in the 4.2 inch mortar (1300 g's low g test). The smaller diameter pins did not provide sufficient travel in either gun.

New pins were made with diameters of .0995 inches, .111 inches and .125 inches having diametral clearance of .001 inches to .0015 inches. These were fired in a 4.2 inch mortar with none of them moving a sufficient distance. Drop tests were run on these larger diameter pins resulting in drop safety being achieved from a drop of 25 feet, however, above 25 feet the travel of the pin was occasionally far enough so as to no longer block the slider and at 40 feet the setback pin moved the necessary distance in every case. All of these results were obtained using an 81 mm. mortar shell as the drop test device. All tests were run with the shell in a vertical position giving the maximum impulse to the setback pin.

The clearance was increased to .005 inches and four different size pins were used, all of which moved the required distance. The pins tested were .093 inches. .0995 inches, .111 inches, and .125 inches. These same units were drop tested from a distance of 20 feet and in no case did the pin move a sufficient distance to permit motion of the slider. With the exception of the .125 inch pin all of the pins moved between .025 and .030 inches at a drop height of 20 feet, which results in a locking engagement of from .025 to .030 inches. The .125 inch diameter moved somewhat further. When drop testing the SHEARFLOD setback pin the bias and return spring is left out to permit measurement of the actual motion of the pin. This spring would reduce the travel of the setback pin in an actual case. The springs are included in the test firing of the entire S & A device.

The SHEARFLOD setback pin is thus capable of experiencing at least a 20 foot drop height without releasing the slider which is a significant improvement over the equivalent spring mass setback system.

## 5. Discussion

The subject contract was to explore the possibilities of the SEOD device in an artillery S & A. A great deal has been learned about this device when used in an artillery environment from this contract. Several items have since been proven feasible using the SECO in other munitions. With the combined experience of these programs plus the continuing in-house research and development efforts that have been going on at the Breed Corporation a great deal of confidence has now been gained in the use of the SECO in ordnance items. Although some problems were encountered in this first feasibility study on the SECO applied to the M125 booster, no serious problems appeared and the problems that did arise appear to have been solved. The puncturing of the foil seal by the wood chips, for example, resulted because the leads were not assembled into the S & A unit resulting in three large holes through which contamination could enter. Once these holes were closed none of the foil seals punctured from this cause. The one which did puncture was due to the fact that the two spin locks momentarily released the slider which was then free to move since the setback pin had not been installed in these units. Since the setback pin will safe the unit for up to a 20 foot drop onto a steel plate, it is unlikely that the setback pin would be removed as a detent during a jumble test. The seven foot drop, jolt and vibration tests were all successfully passed with the exception of a minor problem which occurred due to the delay detonators breaking through the slider and jamming the slider. When this section was thickened, no such problem occurred.

During this contract improvements were made in the design from the manufacturability standpoint which should reduce the manufacturing costs. In production the item is expected to be less expensive than the now standard M125. In addition, the size of the unit has been reduced below the standard M125 to permit its use in a larger variety of projectiles.

The reliability of this S & A should be better than the standard M125 due to the three separate explosive trains which are present. This, it is believed, will result in the extremely low dud rate desired for artillery ammunition.

Perhaps the most significant advantage of this system lies in collateral savings by significantly reducing the complexity needed in the main artillery fuze. This reduction in complexity further should improve the reliability of the entire projectile.

6. Recommendations for Future Work

Although it is strongly felt that the S & A that was the product of this contract could be quickly readied for production with the cost savings and reliability improvements discussed above, it is nevertheless felt that additional work could be done to improve the design in the safety area.

The three places where it is felt that improvements from the safety standpoint could be accomplished are in the foil seal, the centrifugal weights and the setback system. Out of work conducted concurrently with this contract came a new concept in fuzing called, "Total Immersion Fuzing". As applied to this problem this would involve eliminating the foil seal on the SEOD and filling the entire S & A mechanism with the appropriate fluid, then sealing the entire mechanism with a considerably stronger hermetic seal. All parts within the fuze would now be immersed totally in fluid. The setback system for example instead of being a SHEARFLOD would now become a SEOD type device. A SHEARFLOD will selectively respond to high acceleration pulses due to the pseudoplasticity of the compounds used. In other words, for the same energy pulse a SHEARFLOD will move further under a high average acceleration than it will under a low acceleration. A SEOD, on the other hand, selectively attenuates high acceleration pulses responding relatively more to low g pulses than to high g pulses. This is due to the fact that the SEOD responds to the square root of the applied force whereas the SHEARFLOD responds to the force raised to some power greater than 1. The net effect of this is that a SEOD could be designed not to respond to forty foot or even significantly higher drops, thus rendering the fuze considerably more drop safe.

The spin locks on the slider also would become SEODs with short delays and thus will not respond to the type of jolt environment which caused the two pins to release the slider in the jolt test described above, thus, again rendering the item considerably safer.

By sealing the entire S & A device as opposed to just sealing the SEOD, the S & A can now be rendered resettable so that if for any possible reason arming is initiated, then stopped, the unit will reset itself to its initial state.

Finally, the immersion of all parts of the S & A device in a damping fluid greatly reduces the effects of rough handling or vibrations rendering the fuze far more resistant to these types of environments. Similarly, the immersion of all parts in this fluid followed by hermetically sealing the S & A renders the item insensitive to storage under adverse environments and even permits storage under water. In addition, by the use of total immersion techniques, a mechanism can be included within the S & A device which checks for the presence of fluid and renders the munition fail safe if fluid is not present.

By virtue of the safety and other advantages that total immersion fuzing has to offer, it is therefore strongly recommended that in addition to carrying forward the S & A device as designed in this contract, that an additional effort be started to adapt the advantages of total immersion fuzing to an S & A device to replace the standard M125.

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APPENDIX 1

TENTATIVE

MILITARY SPECIFICATION

ARTILLERY S & A BOOSTER

By

BREED CORPORATION

1. Scope.

1.1 This specification covers one type of safety and arming device for use with artillery ammunition.

2. Applicable Documents. (Not available at this time.)

3. Requirements.

3.1 Samples.

3.1.1 First Article Approval Sample. (Not applicable at this time.)

3.1.2 Supplemental Samples. (Not applicable at this time.)

3.1.3 Comparison Sample. (Not applicable at this time.)

3.2 Construction. The device shall be constructed in accordance with the applicable drawings (Breed Corporation No. 508970).

3.2.1 Materials. Materials shall be those specified by the applicable drawings.

3.2.2 Dimensions and Technical Notes.

3.2.2.1 Listed. Those dimensions and technical requirements listed in the preliminary classification of defects are mandatory.

3.2.2.2 Unlisted. The contractor may propose changes to characteristics shown on the drawings but not listed in the Classification of Defects, for the purpose of adapting the item to established manufacturing practices. Such proposals must be accompanied by evidence that the change does not affect the design and that all requirements will be met. If the Government confirms the contention of the contractor, the change will be approved for the duration of the contract. In case of dispute, the characteristics of the drawings shall apply. Approval of a change under provisions of this paragraph does not relieve the contractor from establishing and maintaining an adequate quality assurance program as elsewhere required. Provisions of this paragraph shall not be used to obtain approval for use of discrepant material (i.e. produced before approval is obtained); or for design changes, which should be required in accordance with change provisions of the contract document.

3.2.2.3 Interchangeability. The contractor will not assume, nor does the Government guarantee that all possible combinations of tolerance permitted by the drawings and specifications will consistently satisfy the test requirements without the possibility of selective assembly. Therefore, the manufacturer is obligated to choose those combinations of tolerances and fits within the limits of the specifications and drawings that best suit his process needs and still satisfy the test requirements.

3.3 Performance requirements. The performance requirements contained herein are mandatory.

3.3.1 Operating requirements.

3.3.1.1 Non-arming. The device shall not arm if spun at 1000 rpm for 10 seconds at any temperature from -65°F to 160°F with the safety setback pin removed.

3.3.1.1.1 The setback pin shall not arm when assembled into an 81 mm. mortar shell and dropped from 20 feet onto a steel plate at all temperatures from -65°F to 160°F.

3.3.1.2 Arming. The device shall arm between 35 to 60 turns when operated at any temperature from -65°F to 165°F and at any spin rate from 2,000 rpm to 30,000 rpm with the safety setback pin present and removed.

3.3.1.2.1 The setback pin shall permit arming of the slider when assembled into a 175 mm. artillery shell and dropped from 100 feet onto a steel plate at all temperatures from -65°F to 160°F.

3.3.1.3 Ballistic functioning.

3.3.1.3.1 First article approval sample. The device shall function on impact with a dummy fuze warhead when fired from a 4.2 inch mortar with 6 increments.

3.3.1.3.2 Lot acceptance. Not applicable at this time.

3.3.2 Non-operating requirements. Not applicable at this time.

3.3.3 Environmental requirements.

3.3.3.1 Hermetic seal. There shall be no escape of gas or evidence of fluid leakage when the device is initially heated to 175°F, then while hot placed in a helium or nitrogen chamber for a minimum of 30 minutes at a minimum of 30 lbs/sq.in. gage pressure then immersed in a water bath at 175°F ±10° for 60 seconds. The fluid used shall be colored for this test.

3.3.3.2 Transportation vibration. The device shall meet the requirements specified in 3.3.1 following subjection to the transportation vibration tests of MIL-STD 331 Test 104.

3.3.3.3 Jolt. The device shall be safe to dispose of after being subjected to MIL-STD 331 Test 101.

3.3.3.4 Jumble. The device shall be safe to dispose of after being subjected to MIL-STD 331 Test 102.

3.3.3.5 Forty foot drop. The device shall be safe to dispose of after being subjected to MIL-STD 331 Test 103.

3.3.3.6 Five foot drop. The device shall meet the requirements of paragraph 3.3.1 after being subjected to MIL-STD-331 Test 111.

3.3.4 Reliability requirements. Not applicable at this time.

3.4 Workmanship. All parts shall be manufactured and finished in a thoroughly workmanlike manner to insure satisfactory functioning and durability (See MIL-A2550, Condition of Materials, Parts and Assemblies).

3.4.1 Other special requirements: Not applicable at this time.

4. Quality Assurance Provisions.

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Contractor quality assurance system. The contractor shall provide and maintain a quality assurance system in compliance with MIL-I-45208 and Appendix A thereto.

4.2 Government verification. All quality assurance operations performed by the contractor will be subject to Government verification in compliance with MIL-I-45208 and Appendix A thereto.

4.3 First article approval sample. Not applicable at this time.

4.4 Acceptance inspection. Inspection shall be specified in MIL-A-2550 and in this document.

4.4.1 Lot formation. Not applicable at this time.

4.4.2 Sampling. Not applicable at this time.

4.4.3 Lot Acceptance. Not applicable at this time.

4.4.4 Data Recording. Not applicable at this time.

4.4.5 Classification of Defects. (Preliminary)

The assembly shall be inspected by using the Classification of Defects and appropriate drawing.

4.4.5.1 Artillery S & A Booster Assembly (Drawing No. 508970).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| 1 | Timer pin missing | .015 | Visual |
| Major | | | |
| 101 | Slider detent pin missing | 0.65 | Visual |
| 102 | Distance from top of artillery adapter to cover | 0.65 | Gage |
| Minor | | | |
| 201 | Lead cup assembly crimped | 1.5 | Visual |

4.4.5.2 Artillery Adapter (Drawing No. 508983).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | Depth of cavity .495 +.005 | 0.65 | Gage |
| 102 | Small cavity width .664 +.004 | .65 | Gage |
| 103 | Width of cavity large .953 +.004 | .65 | Gage |
| Minor | | | |
| 201 | Overall length 1.490 -.005 | 1.5 | Gage |

| | | | |
|---|---|---|---|
| 202 | Depth of slot .208 +.003 | 1.5 | Gage |
| 203 | Depth of upper cavity .614 +.005 | 1.5 | Gage |
| 204 | Counterbore | 1.5 | Gage |
| 205 | Width of groove .156 +.003 | 1.5 | Gage |
| 206 | Small thread | 1.5 | Gage |
| 207 | Large thread | 1.5 | Gage |
| 208 | Surface finish in cavity | 1.5 | Visual |

4.4.5.3 Lead cup assembly (Drawing No. 508601).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | Diameter of cup assembly | 1.5 | Gage |
| 202 | Length of cup assembly | 1.5 | Gage |

4.4.5.4 Lead cup (Drawing No. 508935).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | O. D. of cup | 1.5 | Gage |
| 202 | Length of cup .335 -.003 | 1.5 | Gage |

| | | | |
|---|---|---|---|
| 203 | I.D. of cup | 1.5 | Gage |

4.4.5.5 Pin timer (Drawing No. 509127).

| Categories | Defects | AQL | Method of inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | Thickness of flat .005 max. | .65 | Gage |
| 102 | Length of pin .320 -.005 | .65 | Gage |
| Minor | | | |
| 201 | Pin small diameter .078 -.005 | 1.5 | Gage |

4.4.5.6 Cover (Drawing No. 509022).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | Depth of groove .049 -.004 | .65 | Gage |
| 102 | Depth of groove .089 -.005 | .65 | Gage |
| Minor | | | |
| 201 | Major diameter 1.620 -.010 | 1.5 | Gage |
| 202 | Position of holes 1.100 ±.002 | 1.5 | Gage |
| 203 | Width of firing pin point .015 -.007 | 1.5 | Gage |

| | | | |
|---|---|---|---|
| 204 | Length of firing pin .004 -.008 | 1.5 | Gage |
| 205 | Location of hole .242 ±.003 | 1.5 | Gage |

4.4.5.7 Slider detent pin (Drawing No. 509095).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | Length of pin .295 -.005 | .65 | Gage |
| Minor | | | |
| 201 | Diameter of pin .156 -.002 | 1.5 | Gage |

4.4.5.8 Slider detent pin spring (Drawing No. 509094).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | Load at .195 | .65 | Spring tester |
| Minor | | | |
| 201 | Diameter | 1.5 | Gage |

4.4.5.9 Slider weight assembly (Drawing No. 508990).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | Detonator staking | 1.5 | Visual |
| 202 | SECO assembly staking | 1.5 | Visual |

4.4.5.10 Slider weight (Drawing No. 503992).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | Thickness .446 -.004 | .65 | Gage |
| 102 | Width .950 -.004 | .65 | Gage |
| Minor | | | |
| 201 | Hole diameter .378 +.006 | 1.5 | Gage |
| 202 | Location of detonator holes .744 ±.003 | 1.5 | Gage |
| 203 | Location of SHEARFLOD hole .330 ±.003 | 1.5 | Gage |
| 204 | Diameter of delay detonator hole and counterbore | 1.5 | Gage |
| 205 | O.D. delay detonator cavity .127 R ±.003 | 1.5 | Gage |
| 206 | Detonator hole .128 +.003 and counterbore | 1.5 | Gage |
| 207 | Depth of setback pin hole .410 +.005 | 1.5 | Gage |
| 208 | Thickness of detonator hole flanges .016 -.003 | 1.5 | Gage |
| 209 | Thickness of slider weight .406 -.005 | 1.5 | Gage |

4.4.5.11 Modified XM-76-E3 50 millisecond delay detonator (Drawing No. 509104).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | O.D. | 1.5 | Gage |
| 202 | Length | 1.5 | Gage |

4.4.5.12 M-55 Stab detonator (Drawing No. 508344).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | Outside diameter | 1.5 | Gage |

4.4.5.13 Slider Lead Cup and RDX (Drawing No. 509103).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Minor | | | |
| 201 | Length | 1.5 | Gage |

4.4.5.14 SHEARFLOD piston (Drawing No. 508994).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | Diameter .092 -.005 | 1.5 | Gage |
| Minor | | | |
| 201 | Surface finish 32 rms | 1.5 | Visual |

| | | | |
|---|---|---|---|
| 202 | Maximum overall length | 1.5 | Gage |

4.4.5.15 SHEARFLOD cylinder (Drawing No. 509101).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | I.D. | .65 | Gage |
| 102 | Outside diameter | 1.5 | Gage |
| Minor | | | |
| 201 | Surface finish 32 rms | 1.5 | Visual |
| 202 | Length | 1.5 | Gage |

4.4.5.16 SHEARFLOD retaining washer (Drawing No. 508995).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | Outside diameter | 1.5 | Gage |

4.4.5.17 SHEARFLOD spring (Drawing No. 508993).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | Load at .100 | 1.5 | Spring tester |
| 202 | Diameter | 1.5 | Gage |

4.4.5.18 SECO assembly (Drawing No. 509100).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | Overall length | 1.5 | Gage |

4.4.5.19 SECO piston assembly (Drawing No. 509129).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | Stake | .65 | Visual |

4.4.5.20 SECO piston (Drawing No. 509125).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | O. D. .2594 ±.001 | .65 | Gage |
| Minor | | | |
| 201 | I.D. .126 +.002 | 1.5 | Gage |
| 202 | Length .195 -.005 | 1.5 | Gage |

4.4.5.21 Foil orifice (Drawing No. 509098).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | Orifice diameter | 1.5 | Comparator |
| 202 | Diameter | 1.5 | Gage |

4.4.5.22 Orifice foil washer (Drawing No. 509379).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | O.D. | 1.5 | Gage |

4.4.5.23 SEOD cylinder (Drawing No. 508933).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| 101 | I.D. | .65 | Gage |
| Minor | | | |
| 201 | Surface finish 8 rms | 1.5 | Visual |
| 202 | Diameter .355 +.003 | 1.5 | Gage |
| 203 | O.D. | 1.5 | Gage |
| 204 | Hole depth .040 +.003 | 1.5 | Gage |
| 205 | Length | 1.5 | Gage |

4.4.5.24 Sealing washer (Drawing No. 508712).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | O.D. | 1.5 | Gage |

4.4.5.25 SEOD closing disc (Drawing No. 502989).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | O.D. | 1.5 | Gage |

4.4.5.26 Retaining washer (Drawing No. 508715).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | Length | 1.5 | Gage |
| 202 | $45^{\circ}$ chamfer | 1.5 | Comparator |
| 203 | O.D. .352 -.004 | 1.5 | Gage |

4.4.5.27 Foil disc (Drawing No. 508714).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | Thickness | 1.5 | Gage |

4.4.5.28 SEOD spring (Drawing No. 508708).

| Categories | Defects | AQL | Method of Inspection |
|---|---|---|---|
| Critical | | | |
| Major | | | |
| Minor | | | |
| 201 | Load at .340 | 1.5 | Spring tester |

4.4.6 Acceptance tests. Not applicable at this time.

4.5 Test conditions and equipment.

4.5.1 Test conditions. Unless otherwise specified, all measurements are to be made at normal ambient room conditions of temperature, relative humidity and altitude. The following table of tolerances shall be applied where applicable to specified test conditions unless otherwise defined in the test procedures:

| | | |
|---|---|---|
| a. | Temperature test chamber | ±5% |
| b. | Relative humidity | ±5% |
| c. | Vibration amplitude | ±10% |
| d. | Shock | ±10% |
| e. | Speed | ±1% |
| f. | Time | ±1% |

4.5.2 Inspection equipment. Inspection equipment shall be in accordance with the design level shown by the applicable EL and of sufficient accuracy and quality to permit performance of the required inspection. Gage and instrument setting shall be a function of the equipment, and independent of the operator. Equipment shall be marked to indicate the limit of acceptance for each test, but shall not be so marked as to reveal classified security information. Test procedures and calibration procedures shall conform to MIL-I-45208 and Appendix A thereto.

4.6 Test procedures. Not applicable at this time.

5. Preparation for delivery. Not applicable at this time.

6. Notes.

6.1 The foregoing purchase description is necessarily limited due to the less than 100 units which have been manufactured to date.

APPENDIX 2

# FAILURE MODE AND EFFECTS ANALYSIS

2.1 Introduction. The following safety failure mode and effects analysis is composed according to paragraph 5.3.2 of MIL-STD-332. "This analysis is a systematic consideration of the effects on fuze safety of such things as omission of parts, breaking of parts, malfunction of parts, out of order sequence, inspection procedures and personnel errors." This is a "one at a time" failure analysis and does not consider the effects of failure of more than one component at a time.

FAILURE MODE AND EFFECT ANALYSIS

| ITEM IDENTIFICATION | FUNCTION | FAILURE MODE | EFFECT ON SUBSYSTEM | EFFECT ON SYSTEM | REMARK |
|---|---|---|---|---|---|
| ARTILLERY ADAPTER | HOUSING FOR S & A PARTS | EXCESSIVE FRICTION IN SLIDER CAVITY | DELAYS OR PREVENTS MOTION OF SLIDER | INCREASED ARMING DISTANCE OR DOES NOT ARM | INCREASES DUD AMMUNITION |
| " | " | EXCESSIVE FRICTION IN SPIN LOCK CAVITIES | DELAYS OR PREVENTS MOTION OF SLIDER | INCREASED ARMING DISTANCE OR FAILURE TO ARM | INCREASE IN DUD AMMUNITION |
| LEAD CUP ASSEMBLY | CARRY EXPLOSION FROM DETONATOR | OMITTED | EXPLOSION NOT CARRIED FROM SUPER-QUICK DETONATOR | SHELL EXPLODES IN DELAY MODE ON SUPER-QUICK SETTING | DECREASED EFFEC-TIVENESS OF SUPERQUICK ROUNDS |
| LEAD CUP | - | - | - | - | - |
| TIMER, PIN | PUSHES ON SEOD PISTON | OMITTED | SLIDER ALIGNS IMMEDIATELY AFTER SETBACK AND SPIN | PREMATURE ARMING | INCREASED DANGER |
| - | - | SHORT | SLIDER PARTIALLY ALIGNS IMMEDIATELY AFTER SETBACK AND SPIN | PREMATURE ARMING | INCREASED DANGER |
| - | - | BENT OR PLACED ON ANGLE | DELAYS OR PREVENTS MOTION OF SLIDER | INCREASES ARMING DISTANCE OR PRE-VENTS ARMING | INCREASE IN DUDS |
| COVER | HOLDS PARTS IN S & A ASSEMBLY | CONTACTS SLIDER | DELAYS OR PREVENTS MOTION OF SLIDER | INCREASES ARMING DISTANCE OR PRE-VENTS ARMING | INCREASE IN DUD RATE |
| - | - | OMITTED | DELAY DETONATORS WILL NOT FUNCTION | SHELL WILL NOT FUNCTION IN DELAY MODE | INCREASE DUDS |

FAILURE MODE AND EFFECT ANALYSIS

| ITEM IDENTIFICATION | FUNCTION | FAILURE MODE | EFFECT ON | | REMARKS |
|---|---|---|---|---|---|
| | | | SUBSYSTEM | SYSTEM | |
| SCREW MACHINE FLAT HEAD | HOLDS COVER TO ARTILLERY ADAPTER | - | - | - | - |
| PIN, SLIDER DETENT | DETENTS SLIDER UNTIL THRESHOLD SPIN IS ACHIEVED | DOES NOT MOVE OUT DURING SPIN | SLIDER CANNOT MOVE | ARMING DOES NOT OCCUR | DUD AMMUNITION |
| - | - | OMITTED | ONE LESS DETENT ON SLIDER | - | DECREASED SAFETY |
| SPRING, SLIDER DETENT | HOLDS DETENT PIN IN SLIDER | DOES NOT PERMIT MOTION OF DETENT PIN | SLIDER IS NOT RELEASED | ARMING DOES NOT OCCUR | INCREASE IN DUD AMMUNITION |
| " | - | OMITTED | ONE LESS DETENT ON SLIDER | - | DECREASED SAFETY |
| SLIDER, WEIGHT ASSEMBLY | CARRIES DETONATOR | OMITTED | WILL NOT ARM | - | DUD |
| WEIGHT, SLIDER | ON SPIN PROVIDES POWERING FORCE FOR ARMING DELAY | EXCESSIVE FRICTION | DELAYS OR PREVENTS SLIDER MOTION | INCREASE ARMING DISTANCE OR NO ARMING CONDITION | INCREASED DUDS |
| MODIFIED XM-76-E3 50 MILLISECOND DELAY DETONATOR | PROVIDES DELAYED FUNCTIONING ON DELAY SETTING | BURNS TOO RAPIDLY | EXPLOSION CARRIED TO MAIN CHARGE TOO FAST | SHELL EXPLODES TOO EARLY | DECREASED EFFECTIVENESS AGAINST DESIRED TARGET |
| DETONATOR, STAB, M55 | INITIATES LEAD IN SUPERQUICK MODE | OMITTED | S & A DOES NOT RESPOND TO MAIN FUZE FUNCTION | FUZE FUNCTIONS ONLY IN DELAY MODE ON IMPACT | DECREASED EFFECTIVENESS AGAINST DESIRED TARGET |

# FAILURE MODE AND EFFECT ANALYSIS

| ITEM IDENTIFICATION | FUNCTION | FAILURE MODE | EFFECT ON | | REMARKS |
|---|---|---|---|---|---|
| | | | SUBSYSTEM | SYSTEM | |
| SLIDER LEAD CUP AND ROX | CARRIES EXPLOSION FROM DETONATORS TO LEAD CUP ASSEMBLY BELOW M55 | OMITTED | CHARGE NOT CARRIED FROM M55 TO LEAD CUP ASSEMBLY | SHELL FUNCTIONS IN DELAY MODE ON IMPACT ONLY | DECREASED EFFECTIVENESS AGAINST DESIRED TARGET |
| PISTON, SHEARFLOD | DETENTS SLIDER ASSEMBLY UNTIL SETBACK | MOTION DELAYED | SLIDER ASSEMBLY NOT RELEASED | ARMING DOES NOT OCCUR | INCREASE IN DUD AMMUNITION |
| - | - | OMITTED | ONE LESS DETENT ON SLIDER | - | DECREASED SAFETY |
| CLYINDER, SHEARFLOD | HOUSES SHEARFLOD PISTON | EXCESSIVELY RETARDS MOTION OF SHEARFLOD PISTON | SLIDER ASSEMBLY IS NOT RELEASED | ARMING DOES NOT OCCUR | INCREASED DUDS |
| WASHER, RETAINING SHEARFLOD | LOCATES STARTING POSITION OF SHEARFLOD PISTON | OMITTED | EXCESSIVE TRAVEL OF SHEARFLOD PISTON SO THAT SLIDER IS NOT RELEASED | ARMING DOES NOT OCCUR | INCREASED DUDS |
| - | - | EXERTS FRICTION FORCE ON SHEARFLOD PISTON | SLIDER IS NOT RELEASED | ARMING DOES NOT OCCUR | INCREASED DUD AMMUNITION |
| SPRING, SHEARFLOD | IMPOSES BIAS SETBACK ACCELERATION ON SHEARFLOD PISTON | EXCESSIVELY RESTRAINS MOTION OF SHEARFLOD PISTON | SLIDER IS NOT RELEASED | ARMING DOES NOT OCCUR | INCREASE IN DUD AMMUNITION |
| - | - | OMITTED | ONE LESS DETENT ON SLIDER | - | DECREASED SAFETY |
| SEOU ASSEMBLY | PROVIDES SAFE SEPARATION DELAY | OMITTED | INSTANTANEOUS ARMING ON LAUNCH | ARMED PROJECTILE IS LAUNCHED | INCREASED DANGER |

## FAILURE MODE AND EFFECT ANALYSIS

| ITEM IDENTIFICATION | FUNCTION | FAILURE MODE | EFFECT ON SUBSYSTEM | EFFECT ON SYSTEM | REMARKS |
|---|---|---|---|---|---|
| - | - | FLUID LEAKS FROM ASSEMBLY | ARMING DELAY LOST | ARMED PROJECTILE LAUNCHED | INCREASED DANGER |
| SEOD PISTON ASSEMBLY | PROVIDES RESTRICTION TO FLUID FLOW | OMITTED | SLIDER MOTION NOT RESTRAINED | LAUNCHING OF ARMED PROJECTILES | INCREASED DANGER |
| - | - | DOMINANT FLOW OF FLUID DOES NOT OCCUR THROUGH ORIFICE | SLIDER ALIGNS TOO SOON | SEPARATION DISTANCE DECREASED | INCREASED DANGER |
| PISTON, SEOD | - | EXCESSIVE FRICTION RESTRAINS MOTION OR PISTON | SLIDER MOTION RESTRAINED | ARMING OCCURS TOO LATE OR NOT AT ALL | INCREASED DUDS |
| ORIFICE, FOIL | PROVIDES FLOW RESISTANCE FOR ARMING DELAY | RESISTANCE TOO SMALL OR PIECE OMITTED | SLIDER ALIGNS TOO SOON | DECREASED ARMING DELAY | INCREASED DANGER |
| - | | RESISTANCE TOO LARGE OR HOLE PLUGGED | SLIDER MOTION TOO SLOW | ARMING OCCURS TOO LATE OR NOT AT ALL | INCREASED DUDS |
| ORIFICE, FOIL WASHER | RETAINS AND SEALS ORIFICE FOIL TO PISTON ASSEMBLY | OMITTED OR DOES NOT SEAL | SLIDER MOTION TOO FAST | ARMING OCCURS TOO SOON | INCREASED DANGER |
| CYLINDER, SEOD | CONTAINS FLUID AND SEOD PISTON ASSEMBLY | EXERTS EXCESSIVE FRICTION ON SEOD PISTON | SLIDER MOTION TOO SLOW | ARMING OCCURS TOO LATE | INCREASED DUDS |
| WASHER, SEALING | SUPPORTS CLOSING DISC | OMITTED | FLUID IS NOT RETAINED IN SEOD | ARMING DELAY LOST | INCREASED DANGER |

FAILURE MODE AND EFFECT ANALYSIS

| ITEM IDENTIFICATION | FUNCTION | FAILURE MODE | EFFECT ON | | REMARKS |
|---|---|---|---|---|---|
| | | | SUBSYSTEM | SYSTEM | |
| DISC, SEOD CLOSING | SEALED FLUID IN SEOD | FLUID LEAKS OUT | SLIDER ALIGNS TOO RAPIDLY | SHELL IS ARMED TOO SOON | INCREASED DANGER |
| WASHER, RETAINING | HELPS SEAL SEOD AND GUIDES TIMER PIN | OMITTED | SLIDER ALIGNS TOO RAPIDLY | PROJECTILE ARMS TOO SOON | INCREASED DANGER |
| - | - | EXCESSIVE FRICTION ON TIMER PIN | SLIDER ALIGNS TOO SLOWLY OR NOT AT ALL | INCREASED ARMING DISTANCE OR FAILURE TO ARM | INCREASED DUDS |
| DISC, FOIL | SEALS SEOD | FLUID LEAKS | SLIDER ALIGNS TOO RAPIDLY | ARMING OCCURS TOO SOON | INCREASED DANGER |
| SPRING, SEOD | HOLDS SEOD PISTON AT PROPER END OF CYLINDER | DOES NOT RETAIN PISTON AT PROPER END OF CYLINDER OF OMITTED | SLIDER ALIGNS TOO SOON | ARMING OCCURS TOO SOON | INCREASED DANGER |
| - | - | RESTRAINS OR PREVENTS MOTION OF PISTON | SLIDER ALIGNS TOO LATE OR NOT AT ALL | ARMING OCCURS TOO LATE OR NOT AT ALL | INCREASED DUDS |

## APPENDIX 3

## SAFETY STATEMENT

The artillery S & A booster assembly depicted in Breed Corporation Drawing No. 508970 incorporates the following safety features:

(1) SEOD constant turns to arm arming delay,

(2) two spin actuated slider detent lock pins, and,

(3) one setback integrating SHEARFLOD slider detent lock.

The only hazardous situations: omission of one of the critical parts or loss of SEOD fluid.

The only precautions that need be taken are to check visually through the cover to see that the slider is in the out-of-line position while assembling units and to check for presence of oil leakage onto exterior parts.

# APPENDIX 4

## A POINT DETONATING ARTILLERY FUZE

# A POINT DETONATING ARTILLERY FUZE

## SECTION 1

## SUMMARY

The Breed Corporation proposes to evaluate a point detonating artillery fuze costing one-half the current standard M557 fuze and which also contains an impact backup, self-destruct system that virtually assures elimination of artillery duds.

A gearless safety and arming device is used incorporating a SEOD dashpot for a constant distance arming and a SHEARFLOD dashpot for sensing set-back acceleration. This safety and arming device was evaluated under Contract DAAG39-71-C-0001 with Harry Diamond Laboratories which resulted from an unsolicited porposal submitted by the Breed Corporation to the Army Materiel Command to apply Breed Corporation dashpots to the problem of artillery dud elimination.

Three additional artillery fuze designs having special features but incorporating the same safety and arming device are also presented. The first consists of a mating of the density integrating artillery fuze nose recently successfully tested by the Army to the dashpot safety and arming device. The second is a similar matching of a void sensing mechanism recently produced by the Breed Corporation again with the dashpot safety and arming device. The third consists of a special ultra-graze sensitivity mechanism also mated to the dashpot safety and arming device.

A two phase program is presented. Phase One consists of a three month effort for design finalization, limited MIL-STD testing and fabrication of 50 fuzes for proving ground testing. A set of drawings on Breed Corporation

format will be provided at the conclusion of this phase for each design evaluated.

Phase Two is an in-depth evaluation and consists of extensive MIL-STD testing and fabrication, of 2,000 fuzes. Phase Two requires an additional four months.

## SECTION 2

## INTRODUCTION

Breed Corporation proposes to evaluate an Artillery Point Detonating Fuze to replace the M557 which achieves:

- 50% cost reduction
- Redundant self-destruct
- Gearless safety and arming device

Lower cost is achieved by incorporating all fuze functions in the safety and arming device including the arming delay, delayed detonation after impact and self-destruct, thus enabling substantial simplification of the front end or M48 portion of the M557.

Redundant self-destruct is provided by bringing into alignment upon arming, two delay detonators which upon impact, impinge upon stationary firing pins initiating fifty millisecond delayed round detonation.

The gearless safety and arming device utilizes a SEOD dashpot to achieve the arming delay. This S & A was successfully evaluated under Contract No. DAAG39-71-C-0001.

# SECTION 3

## BACKGROUND

Similar to bombs, rockets, and mortars, most artillery fuzing can be divided into the manner by which the round is detonated, i.e. proximity, time or impact. As both proximity and time fuzing typically cost 5 to 10 times impact fuzing, it is estimated that 95% of all bomb, rocket, mortar and artillery fuzing produced is of the impact type.

Even under the present climate of reduced munition procurement, there are reputedly some 20 million impact or point detonating artillery fuzes to be procured this coming fiscal year at an estimated cost of $5 to $6 each. The estimated cost for the proposed fuze is less than three dollars. The $2 to $3 per fuze savings thus amounts to a 40 to 60 million dollar annual savings at current procurement levels.

The Army's standard point detonating fuze is the M557. This fuze consists of a front, M48 portion containing a selectable, superquick or delay, detonation feature, and an M125 arming delay assembly consisting of a centrifugally powered gear train clock mechanism attached to the rear of the M48.

The reliability record of the M557 is in excess of 99% on some rounds and seldom falls below 95%, even on one or two troublesome rounds. There have been few, if any, safety problems attributable to the M557. Any significant improvement to the M557 would thus presumably come first in the area of cost savings and second an improvement in reliability or self-destruct and consequent reduction of dud rounds.

In 1961, the Breed Corporation commenced the development of a family of dashpot timing devices suitable for most munition fuzing. One member of this dashpot family called SEOD (Sharp Edge Orifice Dashpot) was evolved specifically for application to the artillery arming delay. The basic artillery SEOD dashpot consists of a cylinder approximately 3/8" in diameter and 3/4" long, hermetically sealed at each end and filled with a less than 10 centistoke viscosity fluid. Within the cylinder is a piston with a 300 microinch clearance between the piston and cylinder walls. In the center of the piston is contained an approximate .002" diameter orifice .002" in length. For the piston to move within the cylinder the fluid must pass from one side of the piston to the other through this orifice. The piston is biased toward one end of the cylinder by a light coil spring. A .001" thick aluminum foil membrane seals one end of the SEOD cylinder. Upon initiation of the arming delay a probe pierces this membrane and presses upon the piston. As the piston moves relative to the cylinder, a time delay is achieved.

The fluid flow through the piston orifice is almost wholly inertial as the Reynolds number is considerably greater than one. As a consequence viscous forces play an insignificant role in determining the rate of fluid flow giving rise to a time delay which is independent of fluid viscosity and thus temperature.

Due to the dominance of inertial flow, the time delay varies inversely as the square root of the applied force. Both temperature independence and an arming delay varying inversely as the square root of the applied force are necessary to achieve constant distance artillery arming over the required temperature range.

The SEOD adapted to an artillery safety and arming (S & A) device identical in size and function to the M125 plus containing an additional self-destruct feature was presented to the Army several years ago. This presentation resulted in Contract No. DAAG39-71-C-0001 with Harry Diamond Laboratories. During performance upon this contract the originally presented self-destruct system was set aside in favor of an impact backup system conceived by Harry Diamond Laboratories and reduced to a practical design, tested and evaluated by Frankford Arsenal. This impact backup system consisted of a detonator contained in a holder which, in the armed condition, would move forward approximately 1/8" upon round impact against a light bias spring. This forward movement impaled the detonator on a firing pin, initiating the round.

The S & A design evolved and tested during the HDL contract consisted of a centrifugally aligned slider which upon moving to the armed position aligned three explosive trains, a superquick detonator on the fuze axis and two 50 millisecond delay detonators, one either side of the superquick detonator containing the HDL impact backup system. A SEOD dashpot incorporated in the slider assured the desired arming distance before detonator alignment. The slider also contained two centrifugal locks plus a drop safe, SHEARFLOD dashpot, setback acceleration sensor.

It was the successfully achieved object of the HDL contractual effort, for the S & A evolved to be an exact replacement for the M125, at a lesser cost and with the added feature of a redundant, 50 millisecond delay, self-destruct system. Used as an M125 replacement, the center superquick detonator picks up the explosive output from the M48 or any standard electronic or mechanical time fuze, initiating the round. Should the M48, electronic or mechanical time fuze fail, the two 50 millisecond delay, impact initiated, detonators move forward at impact striking firing pins causing round detonation.

Since the artillery fuze functions of arming delay, delayed detonation after impact, and self-destruct backup are all contained in the SEDD S & A, a substantial simplification of the M48 portion of the M557 is possible. This simplification with its attendent cost savings is the primary subject of this proposal.

In addition to an exact functional equivalent to the M557 other background work has been used to provide three additional "front end" mechanisms to provide a complete family of point detonating artillery fuzes utilizing the basic SEDD dashpot S & A.

In recent years the Army has successfully tested a density integrating fuze nose which will penetrate without initiation, thickly foliaged targets detonating only upon striking the target or ground. In this proposal the Army design has been adapted to the dashpot S & A.

The Breed Corporation during the last year has participated in work to evolve a void sensing fuze as an alternate to delayed detonation. The results of this work have been incorporated as a void sensing module which has also been adapted to the basic dashpot S & A.

Finally, the Breed Corporation has utilized its fluid technology capabilities to evolve an ultra-graze sensitive fuze where graze initiation at impact angles of approximately 1° is achievable. This front end module has also been adapted to the basic dashpot S & A.

## SECTION 4

## ORGANIZATIONAL EXPERIENCE

Breed Corporation was founded in 1961 by its current president, Allen Breed. Following attendance in California Institute of Technology and the University of Illinois, he received a B.S. degree from Northwestern University in 1950. Joining with RCA, he progressed from manager of manufacturing and design of the RCA electron tube manufacturing and design of the RCA electron tube manufacturing plant in Cincinnati, Ohio, to director of engineering, Precision Products Division of the Gruen Watch Company. In 1957 he began the Waltham Engineering Corporation which became the REDM Corporation of which he was president. Much of this experience focused on the problems of applying various methods of time delay to military fuzes. In 1961 the Breed Corporation first established the theory and basic computer programs that made possible the ordnance use of time delay devices operating on the principles of fluid dynamics. The successful development of fluid timers has added a new class of timing mechanism that can be used with confidence by fuze designers at a fraction of present fuze costs.

The initial theoretical and computer work was done by David S. Breed, Ph.D., now a vice president and director of research. He holds an A.B. degree from Carleton College, a B.S., and two M.S. degrees from Massachusetts Institute of Technology and a Ph.D. from Columbia University.

Ted Thuen, executive vice president and director of engineering, is a recognized expert in both product and automatic equipment design and has evolved more than sixty fuze designs since joining the Breed Corporation in 1962. He is Norwegian born and educated, receiving an engineering degree in 1956 prior to coming to the United States.

The Breed Corporation's permanent professional staff has been carefully selected from men of outstanding, recognized ability in the fields of time measurement and precision manufacture. All executive personnel and key engineering and technical personnel hold secret security clearances and the main plant has a secret facility clearance.

Modern research and production facilities at a new plant in Fairfield, New Jersey, include:

- An advanced digital computer for control of automated fabrication, design analyses, quality inspection and data acquisition;
- clean-room facilities filtered to 0.5 micron particle removal (class 100), assuring dependable product performance when tolerances are in the order of millionths of an inch;
- model and tool shops for construction of experimental components and tooling for precise, careful fabrication of prototypes and production quantities;
- X-ray, centrifuge and other specifically designed non-destructive inspection and analysis equipment.

- Explosive loading and storage facilities in accordance with Department of Defense safety regulations and New Jersey state law.

The remainder of our 22,000 square feet is occupied by our design, laboratory and production equipment. The main plant is augmented by explosive and sub-tropical environmental test areas.

# SECTION 5

## PROGRAM OBJECTIVES

The objectives of the subject program are:

- To provide a general purpose point detonating artillery fuze at one-half the cost of the current standard M557
- To provide a redundant impact backup, self-destruct feature to virtually eliminate artillery duds
- To provide a point detonating artillery fuze which does not relay upon the manufacturing facilities of the horological industry
- To provide three additional artillery point detonating fuzes utilizing the same S & A device for the special target requirements of canopy penetration, void sensing initiation for the defeat of bunkers and extreme graze sensitivity for tank gun ammunition fuzing.

## SECTION 6

## TECHNICAL DISCUSSIO

### 6.1 Design Summary

A family of four point detonating artillery fuzes is herein described. All four fuzes contain the same basic SEOD dashpot safety and arming device incorporating a redundant, 50 millisecond delay, self-destruct system which was evolved and successfully evaluated under Harry Diamond Laboratories Contract No. DAAG39-71-C-0001. This S & A (See photograph page 13) contains a slider which is urged into the aligned position by round spin and is delayed in attaining the armed position by a SEOD dashpot in such a manner as to result in approximate constant distance arming.

A drop safe SHEARFLOD dashpot must sense setback before the arming delay is permitted to commence. Two additional centrifugal locks on the slider are also provided. Three explosive trains are contained in the slider - a superquick detonator on the fuze axis plus two delay detonators configured in such a manner that upon round impact they move forward approximately 1/8" striking firing pins. Thus, round detonation is assured 50 milliseconds after impact, contingent only upon the slider reaching the armed position. The superquick detonator on the fuze axis can be initiated either by a firing pin or an explosive output from the front end portion of the fuze.

Breed drawing No. 509093 depicts the SEOD S & A module which has been mated to four separate point detonating artillery fuze designs in this proposal. For detailed test results of this S & A performance the progress and final reports of Contract DAAG39-71-C-0001 (Harry Diamond Laboratories) should be consulted. A Frankford Arsenal Report No. #1958 contains a detailed evaluation of the impact backup detonation initiation system.

6.2 M557 Equivalent Plus Redundant Self-destruct

By incorporating all fuze functions in the dashpot safety and arming device, the front end or M48 portion of the M557 need consist of nothing more than a firing pin which strikes the center detonator in the S & A for superquick functioning and a means for preventing this action for delay detonation. A suitable design is depicted in Breed Drawing No. 509122. Superquick or delayed detonation is achieved by a $90^{0}$ turn of a slotted bushing in a manner identical to the M557. Turning the bushing to the superquick setting permits round spin to remove a physical barrier which otherwise prevents rearward movement of the firing pin. A delay setting inhibits removal of this same barrier thereby preventing the firing pin from striking the detonator upon impact. The two delay detonators contained in the S & A slider always assure round initiation 50 milliseconds after impact if round detonation has not already occurred.

Referring to drawing No. 509122, the basic structural member of the fuze is a turned steel body which contains the threads for assembly to the round. The dashpot S & A mechanism is inserted into the rear of the body followed by the booster which is either staked or screwed onto the body. Forward of the S & A mechanism is a heavy portion of the body which serves to provide maximum protection to the S & A at impact when set for delay. A sheetmetal ogive containing a low density plastic filler is secured to the front of the body in such a manner as to give maximum graze sensitivity. Rearward movement of this ogive at impact forces the firing pin into the aligned S & A superquick detonator initiating the round. When set for delay the interruptor acts as a physical barrier to the rearward movement of the firing pin. As always, however, the two delay detonators move forward at impact striking their respective firing pins and thus initiating the round 50 milliseconds after impact.

6.3 Artillery Point Detonating Fuze with Density Integrating Nose

Drawing No. 509138 depicts a point detonating artillery fuze containing a density integrating nose. A similar nose design has recently been reported to have enabled the firing of artillery through jungle canopy with round detonation not occurring until ground impact. The fuze construction selected in this case involves a one piece body ogive design to provide a suitable support for the density integrating nose. A superquick or delay setting has been provided similar to the M557. In this instance a delay setting inhibits the removal of the interrupter with round spin, thereby block the output from the detonator contained in the density integrating nose from reaching the center detonator in the S & A. The round is consequently detonated by the two, 50 millisecond delay, detonators moving forward against their respective firing pins at round impact.

A superquick setting permits the interrupter to move radially outward under round spin thereby enabling the output of the nose detonator to initiate the S & A superquick detonator upon ground impact.

6.4 A Void Sensing Point Detonating Artillery Fuze with a Superquick Option

Drawing No. 509141 depicts a fuze which is settable from the front end for either superquick or void sensing detonation. With either setting the backup delay detonators in the S & A will cause round initiation 50 milliseconds after initial impact if initiation has not already occurred.

When set for void sensing detonation, the firing pin mass moves forward compressing the firing pin spring upon round impact permitting the lock wire to spring outward into the unlock position. The firing pin mass and firing pin remain in this forward position until round deceleration ceases whereupon the firing pin spring propels both the firing pin and firing pin mass into the center, superquick detonator contained in the S & A. Round detonation thus occurs either when the round comes to rest or when the projectile enters an interior void after passing through a barrier, e. g. a bunker. When set for void initiation the keying arrangement between the setting bushing and firing pin permits both rearward movement of the nose portion of the fuze and forward movement of the firing pin at impact without interference.

When set for superquick functioning, the keying arrangement between the firing pin and setting bushing causes the firing pin to be pushed directly into the S & A center detonator as the nose portion of the fuze is moved rearward upon target impact. To minimize inertial forces restricting this rearward firing pin movement, the firing pin breaks free of the firing pin mass through rupturing of the firing pin to firing pin mass staking. This complete void sensing system has been successfully evaluated on the 2.75" rocket munition.

6.5 A Point Detonating Ultra-graze Sensitive Fuze

Drawing No. 509157 depicts a point detonating artillery fuze settable for either superquick or delay detonation and containing in addition an ultra-graze sensitive sealed module which operates when the fuze is set for superquick. The sealed module is a cylinder approximately 3/4" in diameter and 1¼" long which is completely filled with a thin liquid. Contained with the completely filled sealed cylinder is a firing pin and an inertial mass which upon any desired deceleration will move forward releasing the firing pin to be propelled through a thin foil seal into the S & A center detonator. The inertial mass is supported within a cylinder on a special bearing pad arrangement such that the coefficient of friction between the two members is .001. This arrangement effectively eliminates any frictional drag on the forward movement of the inertial mass upon graze impact caused by the transverse, impact acceleration, component. The axial deceleration necessary to cause round detonation can therefore be set as close to 1 g as desired without concern from frictional affects caused by transverse accelerations. This mechanism contains its own spin sensing system which locks the graze sensing mass until the round is deployed.

Should the round strike the nose portion of the fuze, rearward movement of an extension of this nose portion breaks through the sealed can impinging upon and forcing the firing pin directly into the S & A center detonator.

In the delay setting, operation is similar to the M557 equivalent wherein a physical barrier remains in between the firing pin and center detonator thus permitting the two delay detonators with the S & A to cause round initiation.

## SECTION 7

## PROGRAM PLAN

A two phase development program is proposed for the evaluation of a point detonating artillery fuze suitable as an M557 replacement. Phase 1 is an initial feasibility phase to permit a preliminary evaluation to be made. Phase 2 is properly termed advanced development.

### 7.1 Phase 1

The initial phase consists of engineering, design, fabrication, limited MIL-STD testing with final delivery of 50 fuzes for Army evaluation. A set of drawings on Breed Corporation format will be delivered at the completion of the phase. The effort will consist of seven tasks and be completed in three months.

Task 1 - Design Finalization

Task 2 - Centrifuge Evaluation of Arming

Task 3 - Explosive Out-of-line and In-line Propagation Tests

Task 4 - Jolt - Jumble Tests (MIL-STD-331 Tests 101-102)

Task 5 - Five foot Drop Tests (MIL-STD-331 Test 111)

Task 6 - Forty foot Drop Tests (MIL-STD-331 Test 103)

Task 7 - Fabrication and Delivery of 50 Fuzes for Army Evaluation

### 7.2 Phase 2

The second phase constitutes the advanced development phase and consists of containued engineering, redesign, extensive MIL-STD testing and fabrication and delivery of 2000 fuzes for Army evaluation. A revised set of drawings on Breed Corporation format will be delivered at the completion of this four month phase.

The effort consists of seven tasks:

Task 1 - Design Finalization

Task 2 - Centrifuge Evaluation of Arming

Task 3 - Explosive Propagation Tests

Task 4 - Jolt - Jumble Tests (MIL-STD-331 Tests 101-102)

Task 5 - Temperature and Humidity (MIL-STD-331 Test 105)

Task 6 - Transportation Vibration, Procedure II Cycling Method (MIL-STD-331 Test 104)

Task 7 - Fabrication and delivery of 2000 fuzes for Army evaluation

# SECTION 8

## CONCLUSION

For over three decades the U. S. Artillery point detonating fuze requirements have been satisfied by the M557 and predecessor fuzes very similar in design. All have essentially relied upon clockwork mechanism to provide the arming delay, a pyrotechnique delay element in the front portion of the fuze to provide delayed detonation after impact and a firing pin-detonator in the fuze nose which, for superquick operation, flashes back through an uninterrupted channel initiating a detonator in the S & A mechanism. For delayed functioning this channel is blocked thereby resulting in initiation of the S & A detonator by the front end, pyrotechnique delay element.

This basic configuration has been improved and refined over the years to the point where fuzes produced in the last few years have a very enviable reliability and safety record. Recently to handle special target situations, different front end P.D. fuze designs have been added to the basic clockwork S & A mechanism to provide canopy penetration, void sensing for the defeat of bunkers and better graze sensitivity. There also have been several new S & A mechanisms which, however, have all continued to use clockwork gears and pinions to achieve the arming delay. The object of these new S & A designs has primarily been the adaptation of newer manufacturing techniques for the fabrication of clockwork parts, plus the utilization of designs which were more readily adaptable to automated assembly.

The single exception not involving clockwork in the artillery S & A field has been Breed Corporation's SEOD dashpot which was presented to the

Army Materiel Command and successfully evaluated by Harry Diamond Laboratories under Contract No. DAAG39-71-C-0001. In addition to providing a substantially simpler and less costly arming delay device, the small size of the SEOD dashpot permitted the inclusion of a redundant, 50 millisecond delay, impact backup, self-destruct system plus an improved setback sensing device, all in the same volume as occupied by the M125 conventional clockwork S & A.

The subject of this proposal is the adaptation of this proven, artillery S & A module to, first of all, the high volume M557 fuze requirement which would thereby result in a 40 to 60 million dollar annual savings at current procurement levels. This proposal also includes designs for the adaptation of this basic S & A module to three additional point detonating artillery fuzes for the special target situations previously mentioned. In all four designs, the substantial fuze simplification and consequent significant cost savings results from the basic simplicity of a SEOD dashpot delay over clockwork mechanism and by the inclusion within the S & A of the additional function of delayed detonation.

Finally, and perhaps most significant of all, has been the inclusion of a two channel, redundant, self-destruct system in the S & A which should assure the virtual elimination of artillery duds.

APPENDIX 5

Artillery Booster Assembly (Safety Adapter)

Safety and Arming Device including Self-destruct

BREED CORPORATION

20 SPIELMAN ROAD
FAIRFIELD, N. J. 07006
TEL. (201) 227-1200
TELEX: BREEDCORP FFLD 126056

May 23, 1969

Artillery Booster Assembly (Safety Adapter)
Safety and Arming Device Including Self-Destruct

## General

The subject fuze is a further extension of Breed Corporation's "Fluid Dynamic Timer" technology to the artillery safety and arming mechanism field. Two separate fluid flow timers are utilized, one a Sharp Edge Orifice Dashpot "SEOD" for the arming delay and a Liquid Annular Orifice Dashpot "LAOD" for the delayed self-destruct "clean up" should the primary fuze fail. This safety and arming device also incorporates dual environmental sensing to initiate arming (setback and spin) and is interchangeable with the current standard M125 booster assembly or the similar Safety Adapter.

## The Arming Timer "SEOD"

To achieve constant distance arming for any given artillery piece from minimum charge to maximum charge and thus varying bore velocities, the centrifugally powered, arming delay timer, must cause arming to occur as an inverse, square root function of the applied force. For example, a doubling of the linear velocity should cause the arming timer to permit arming in one-half the time to result in the same arming distance. However, doubling the linear velocity also doubles the rotational velocity (spin) which in turn causes a four fold increase in the centrifugal forces powering the arming delay timer. Therefore, the arming timer must operate as the inverse square root of the applied force ($1/\sqrt{4} = 1/2$) if the same arming distance is to be achieved.

In the field of fluid restrictors, the sharp edge orifice permits a volume flow rate as the square root of the upstream pressure.

Another consideration is an arming delay relatively insensitive to temperatures over the $-65^{\circ}F$ to $+160^{\circ}F$ range.

Fortunately, in predominantly inertial fluid flow, the fluid viscosity becomes a second order affect. Thus by appropriate selection of fluid velocity, orifice type and size, and upstream pressure, it is possible to achieve a flow rate that varies as the square root of the upstream pressure and is relatively temperature insensitive.

A third consideration is a suitable seal between piston and cylinder to thereby insure a primary fluid flow through the sharp edge orifice. Breed Corporation's experience with its annular orifice dashpots using low cost, accurate glass pistons and cylinders dictated the selection of a high precision, close fit, between piston and cylinder to assure the proper flow path.

Finally, as rotational velocities vary by a factor of ten in conventional artillery thus causing a ten squared or one hundred times variation in the timer driving force, consideration had to be given to the strength of the dashpot components.

The SEOD presented in the subject fuze has been bench tested and found to operate satisfactorily over the range of driving forces that would be encountered by the subject fuze as well as at the temperature extremes (-65°F to +160°F).

The Self-destruct Timer "LAOD"

Breed Corporation's LAOD uses pressure fluid flow between a spherical piston and a glass cylinder. As the piston is forced through the cylinder, fluid flow between piston and cylinder necessary to permit piston movement gives rise to a time delay. Temperature compensation is achieved by using the differential expansion between piston and cylinder to change the annular orifice or clearance sufficiently to match the fluid viscosity change and thus maintain a constant flow rate. Time delays for three-sixteenth inch piston travel in a one-eighth inch bore, from less than one second to over one year are available. In the subject fuze, a self-destruct delay of five to fifteen minutes from arming was selected as being sufficiently long to permit proper operation of any primary fuze.

Arming Initiation

The arming pin must move in a direction parallel with the fuze axis to unlock the slider. This rearward movement is caused by setback. Once in a free flight, spin is used to both hold the arming pin in the "unlock" position as well as force the slider against the SEOD arming timer, initiating the arming delay. Thus, dual environmental sensing i.e., setback and spin, is necessary to cause arming.

Self-destruct Time Delay Initiation

Movement of the slider into the armed position, in addition to aligning the main explosive train and thus enabling the primary fuze to initiate the round at the proper point or time, also removes a ball detent on the self-destruct timer and aligns an explosive lead to complete the self-destruct explosive train. After a five to fifteen minute delay, assuming a dud primary fuze, a stab detonator is initiated in the self-destruct unit, and the explosion propagates to the main booster lead initiating the round.

Producibility

The subject fuze has been designed around standard, high volume, low cost manufacturing methods such as die castings, plastic moldings, punch press stampings and extrusions and screw machine parts The dashpot components are similarly economically mass produced on glass shrinking and bearing ball manufacturing equipment. In spite of the additional features offered by the subject fuze over the current standard booster assembly and safety adapter, the manufacturing cost is expected to be comparable.

COPY

TABLE I

| ARTILLERY | Arming dist (ft) Min | Arming dist (ft) Max | Spin (rpm) Min | Spin (rpm) Max | Eccentricity (in.) Note 2 | Eccentricity (in.) Note 3 | Setback Accel (g) Min | Setback Accel (g) Max | Velocity (ft/sec) Min | Velocity (ft/sec) Max | Sensitivity Function Non func. | Sensitivity Function Func. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 105 mm How | 125 | 300 | 3800 | 13,500 | .050 | .075 | 1030 | 13000 | 420 | 1550 | Rain drops | 1/2 " plywood at 700 ft/sec or 1/4 " plywood at 2000 ft/sec |
| 155 mm How | 220 | 300 | 3200 | 8,750 | " | " | 1400 | 9900 | 680 | 1050 | | |
| 8-in. How | 225 | 500 | 3000 | 25,000 | " | " | 1910 | 8300 | 820 | 1950 | | |
| 175 mm Gun | 205 | 500 | 8730 | 15,660 | " | " | 2500 | 12700 | 1675 | 3000 | | |
| TANK | | | | | | | | | | | | |
| 76 mm | 25 | 65 | | 10,000 | | | | 15900 | | 2400 | 1/8"ply-wood | 1" plywood |
| 90 mm | | | | 21,700 | | | | 20600 | | 2670 | | " |
| 105 mm | | | | 23,200 | | | | 14800 | | 2100 | | " |
| 120 mm | | | | 15,250 | | | | 13300 | | 2500 | | " |
| 152 mm | | | | 6,800 | | | | 25400 | | 2260 | " | " |
| MORTAR | 300 | 5sec | | | | | | | | | | |
| 60 mm (Note 4) | | | 0 | | | | 560 | 6960 | 156 | 520 | | Water and soft earth, marsh or snow |
| 81 mm | | | 0 | 3,60[illegible] | .050 | | 690 | 7500 | 100 | 865 | | |
| 4.2 Inch | | | 2300 | 9,6[illegible] | .050 | .075 | 1170 | 10000 | 250 | 1000 | | |

NOTES:

1. Above data is for nominal conditions at 70° ± 15°F; allowance must be made for minimum conditions under cold temperatures (-40°F) and worn gun conditions and maximum conditions of excess pressure and temperature (+155°F) for safety release conditions.

2. Eccentricity noted is that evident in existing weapons as a result of clearance between projectile bourrelet and weapon rifling at projectile launch.

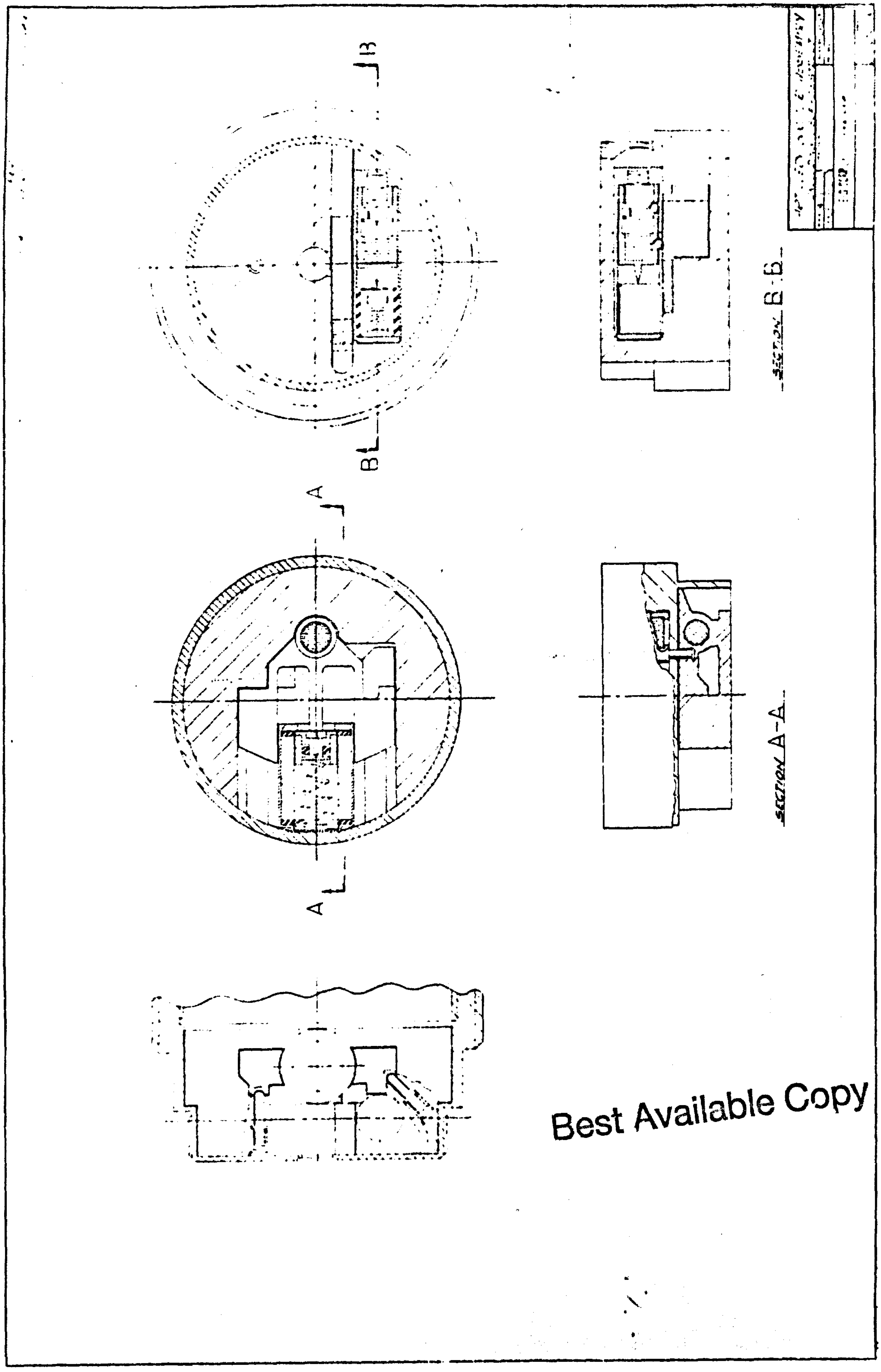
3. Eccentricity noted is that desirable condition to be met to provide assurance during laboratory testing of meeting that eccentricity condition predicted for actual ballistic environment. Laboratory testing should verify operation in four quadrants of eccentricity.

4. Data on 60 mm is for information only and is not part of this problem.

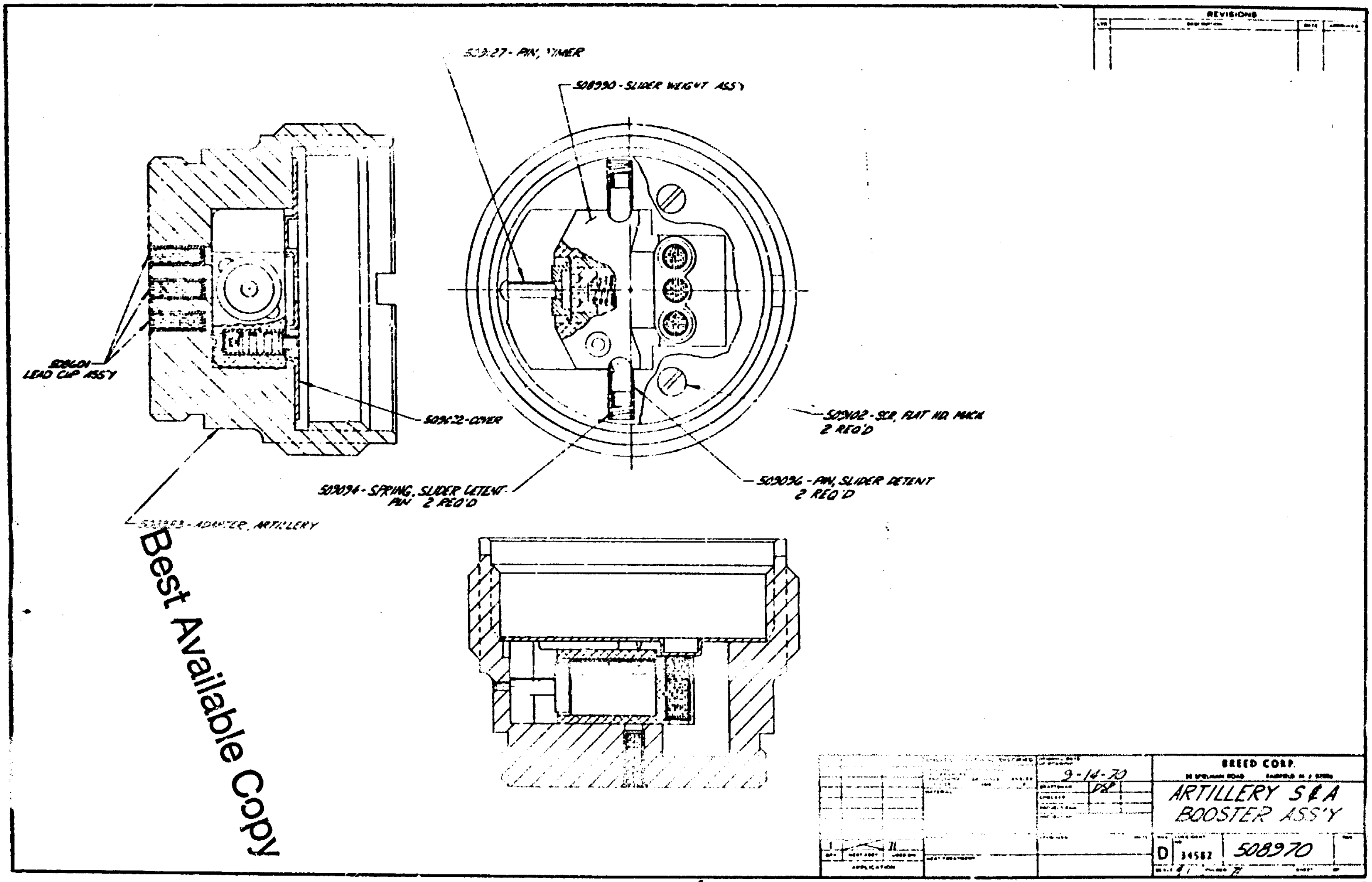
APPENDIX 6

DRAWINGS

(Partial)

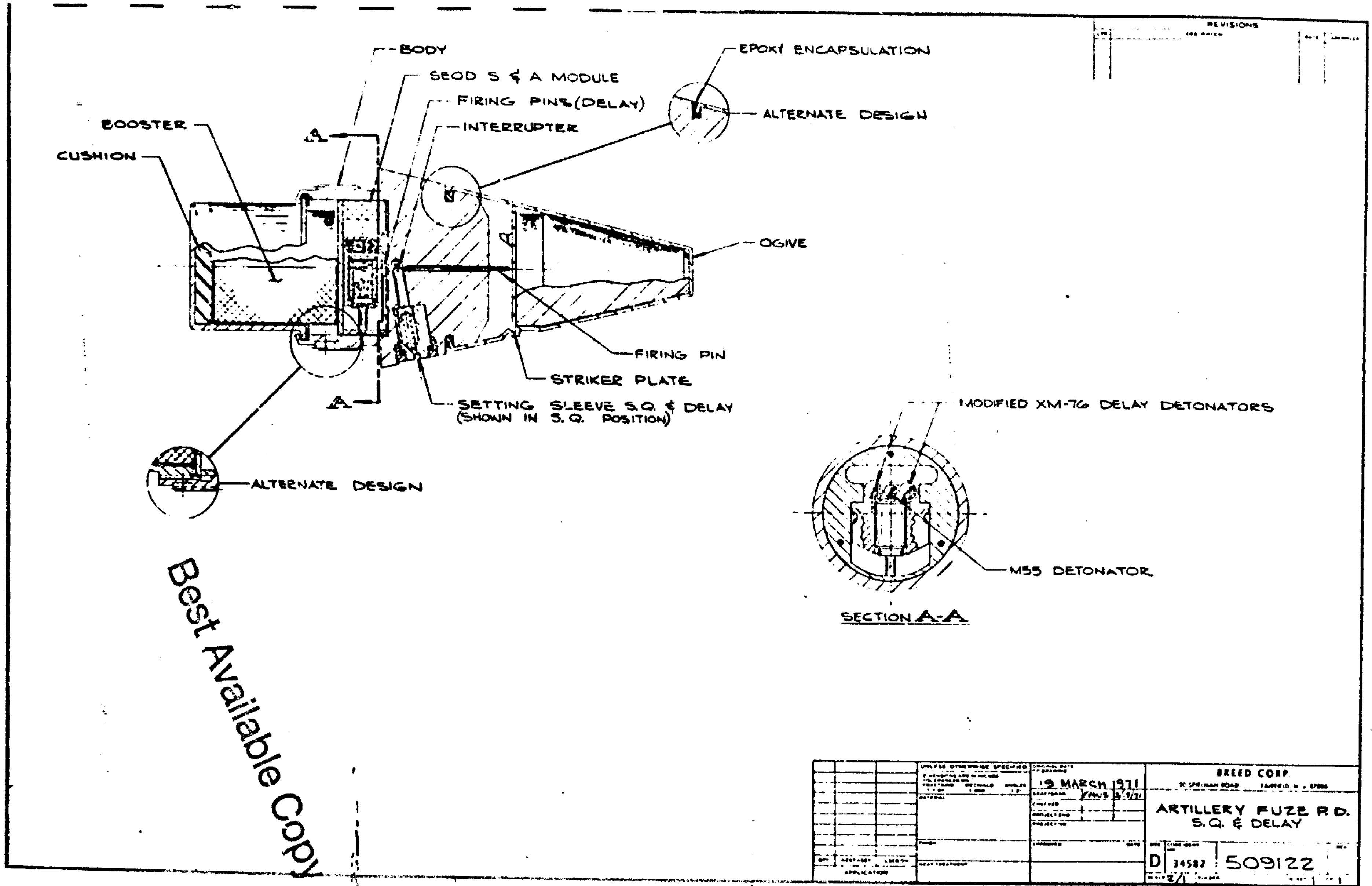


6-2

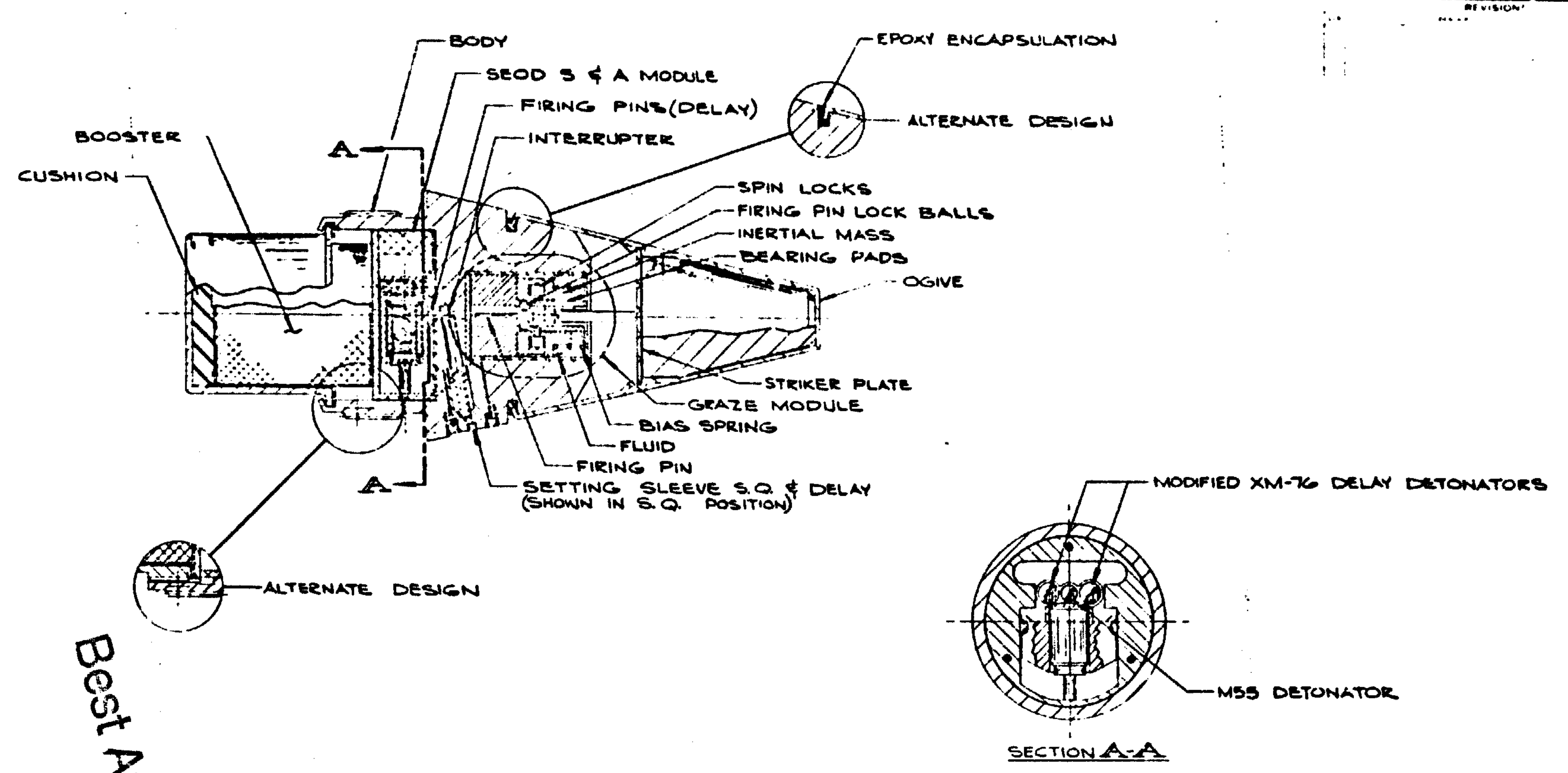



Best Available Copy

6-3



REVISIONS
BODY
SEOD S & A MODULE
FIRING PINS (DELAY)
INTERRUPTER
EPOXY ENCAPSULATION
ALTERNATE DESIGN
BOOSTER
CUSHION
A
OGIVE
FIRING PIN
STRIKER PLATE
SETTING SLEEVE S.Q. & DELAY (SHOWN IN S.Q. POSITION)
ALTERNATE DESIGN
MODIFIED XM-76 DELAY DETONATORS
M55 DETONATOR
SECTION A-A
19 MARCH 1971
BREED CORP.
ARTILLERY FUZE P.D. S.Q. & DELAY
D 34582 509122




FREED CORP

19 MARCH 1971

ARTILLERY FUZE P.D.
WITH GRAZE SENSING MODULE
S.Q. & DELAY

D 34582 509157

4-4